HDH: HV – HILS

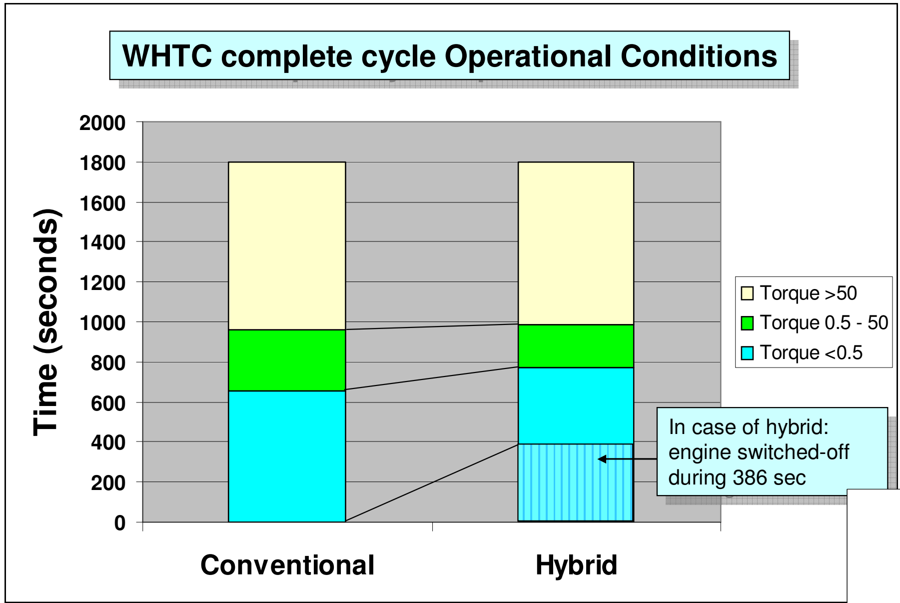
Hybrid vehicles
Hardware in the loop simulation

HDH Meeting 19.May 2010 Brussels

Baseline, operational conditions

- Combustion engines in hybrid powertrains operate in different load/speed areas than in conventional powertrains
- Some (large) areas of the engine map may never be used in real word HV mode
- WHTC – WHSC engine cycles will not be representative
- Combustion engines is only operational in case of ‘power-demand’

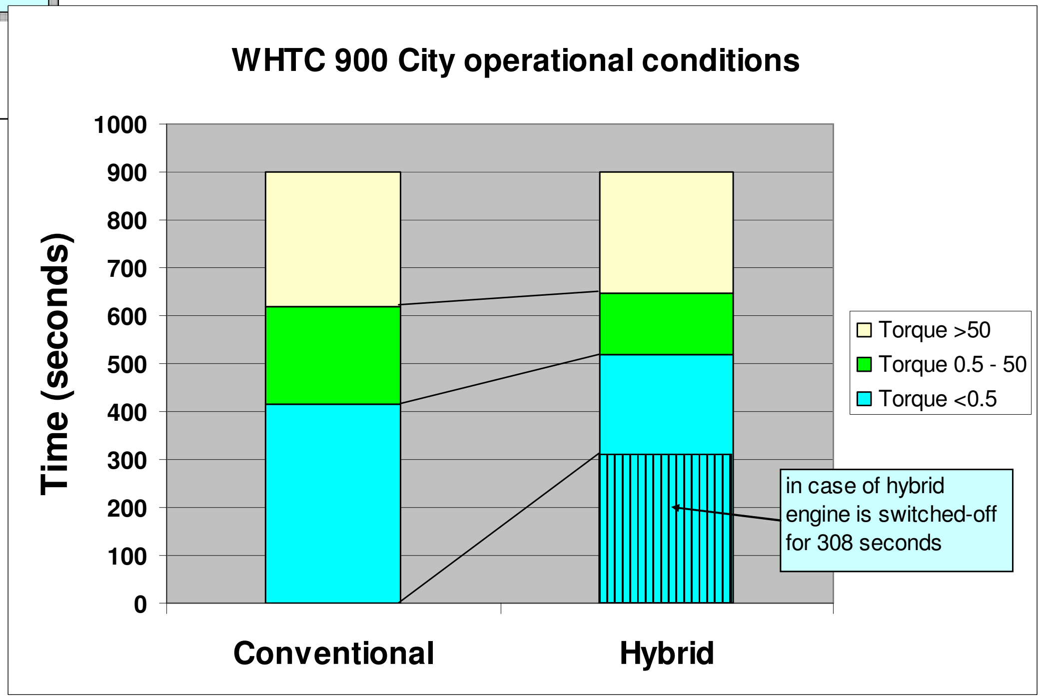
Parallel hybrid



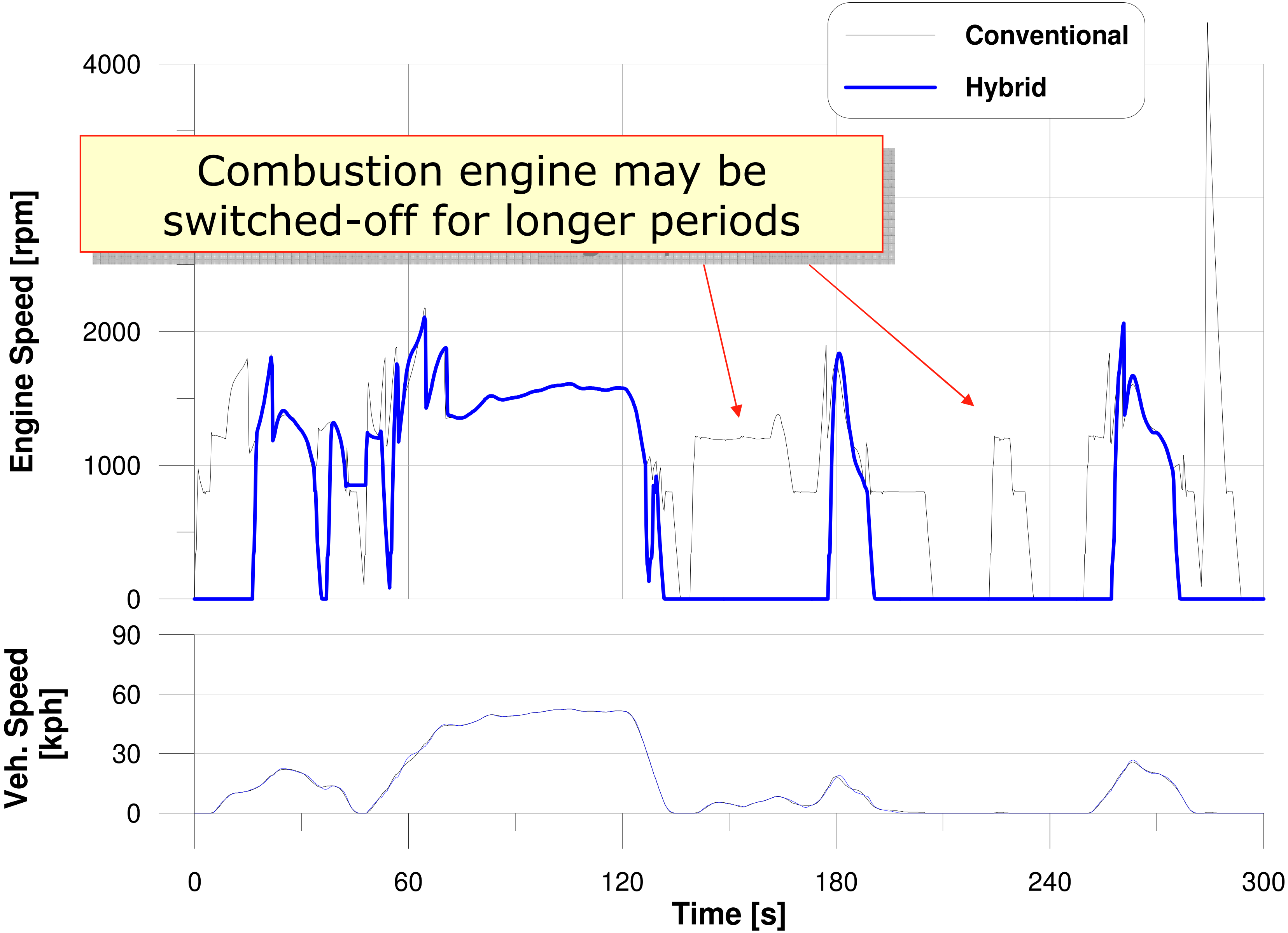
Engine load pattern shifting to higher loads in case of hybrid

Example

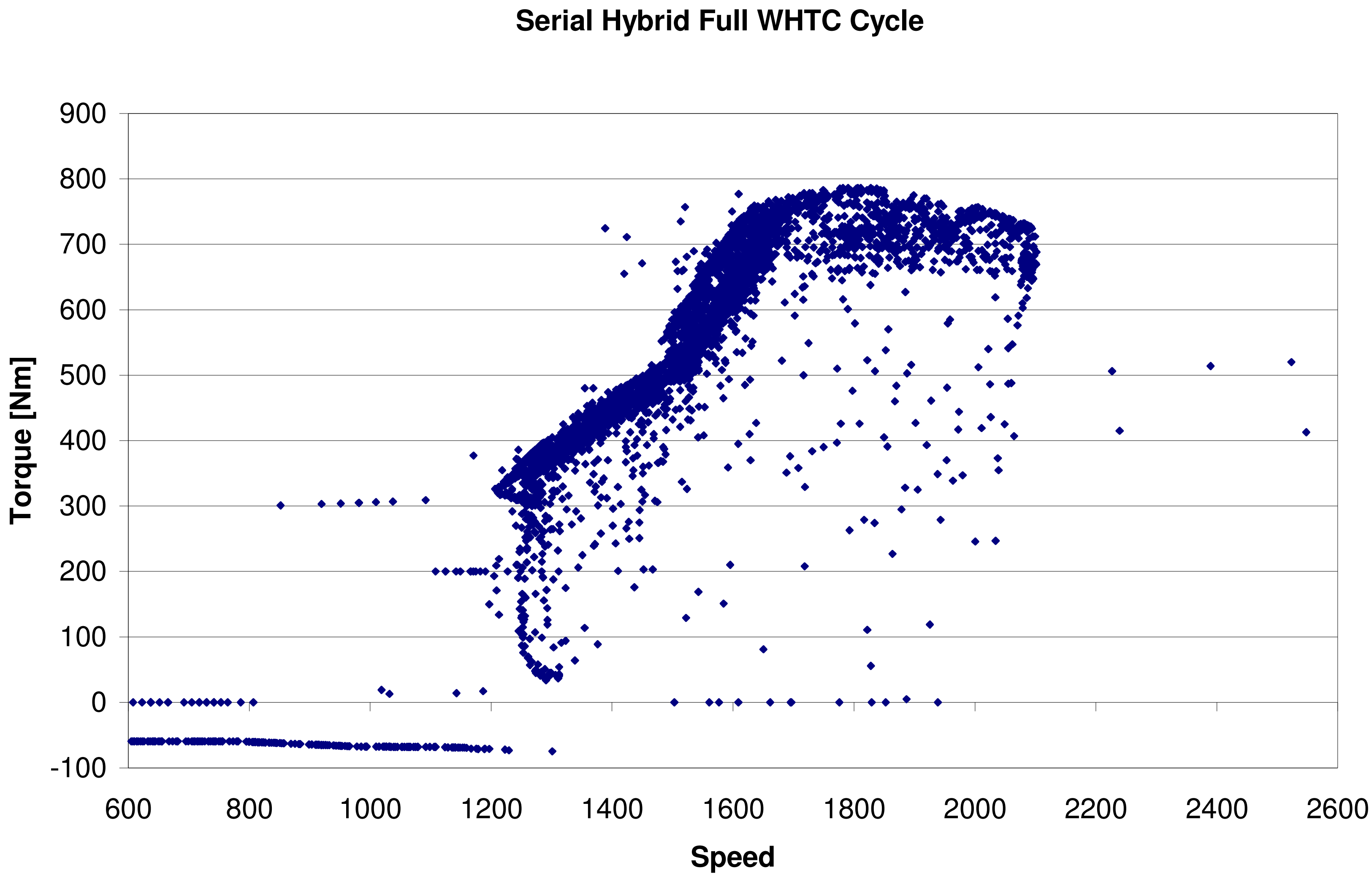
3.5 ton truck with parallel hybrid



Parallel hybrid (2)



Serial hybrid



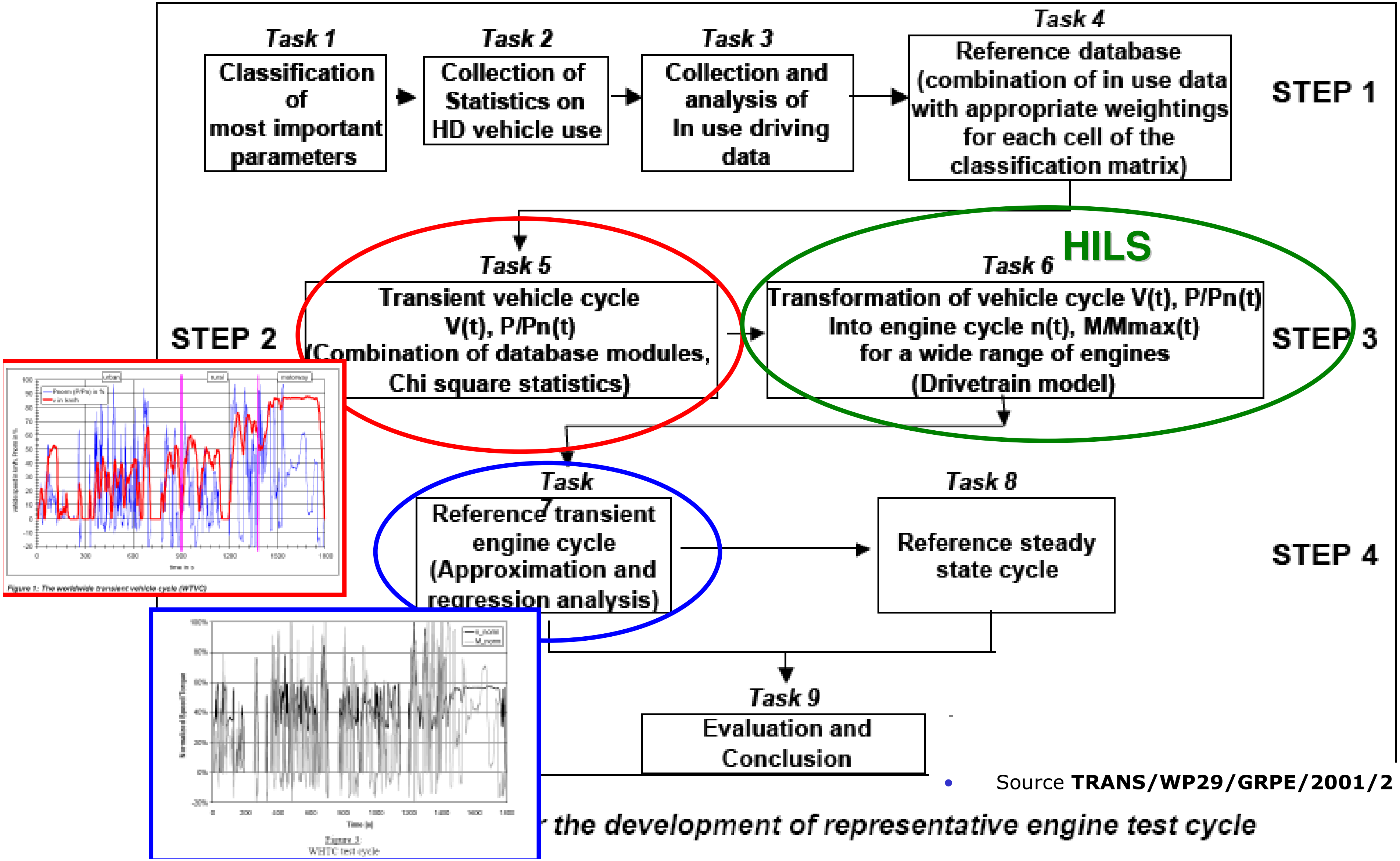
Scope

- Emissions (NOx, HC, CO, PM) of HV's must remain – in real world application – at same level as conventional vehicles
- HV powertrain is optimised to obtain lowest energy consumption /CO2
- SOC (state of charge) must remain neutral over emission testing cycle (no external energy)
- To achieve best cost-efficiency of powertrain system

Options to certify engines for HV's

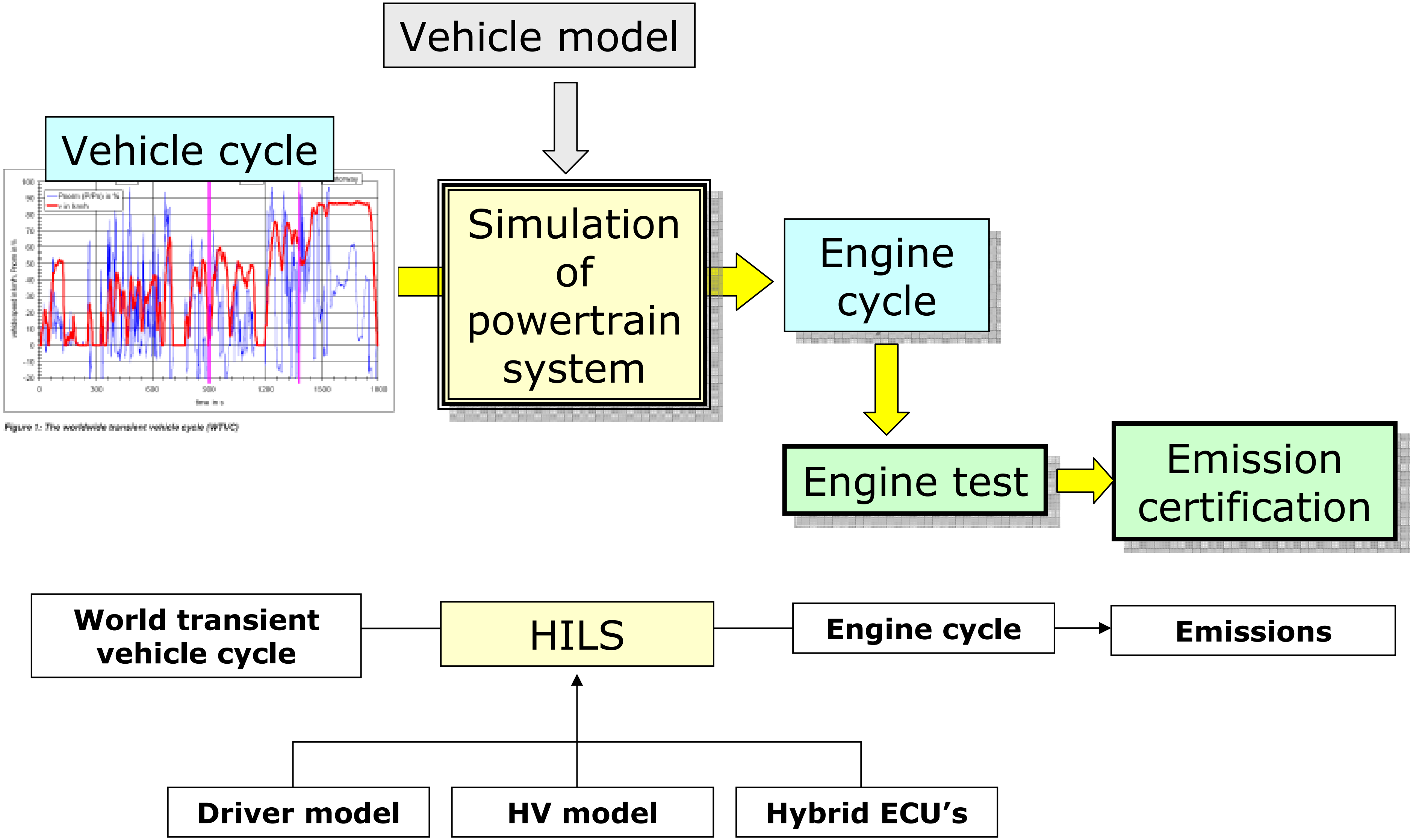
Engine certified as today (ETC, WHTC, US-FTP)	No change to existing regulations	Engine may be operated in real driving under completely different conditions
Certification of complete vehicle on vehicle dyno	Truly reflecting the real vehicle	Controlling of test conditions, read-across for different vehicle-types within family,
System bench method, complete powertrain system to be tested on test bed	Complete system to be tested	Control? Bulky installation on test bed (with transmission),
HILS	Simple testing of engine only, cost-effective	extensive work to describe HILS on a regulatory-basis, Japanese std available

WHTC development…HILS

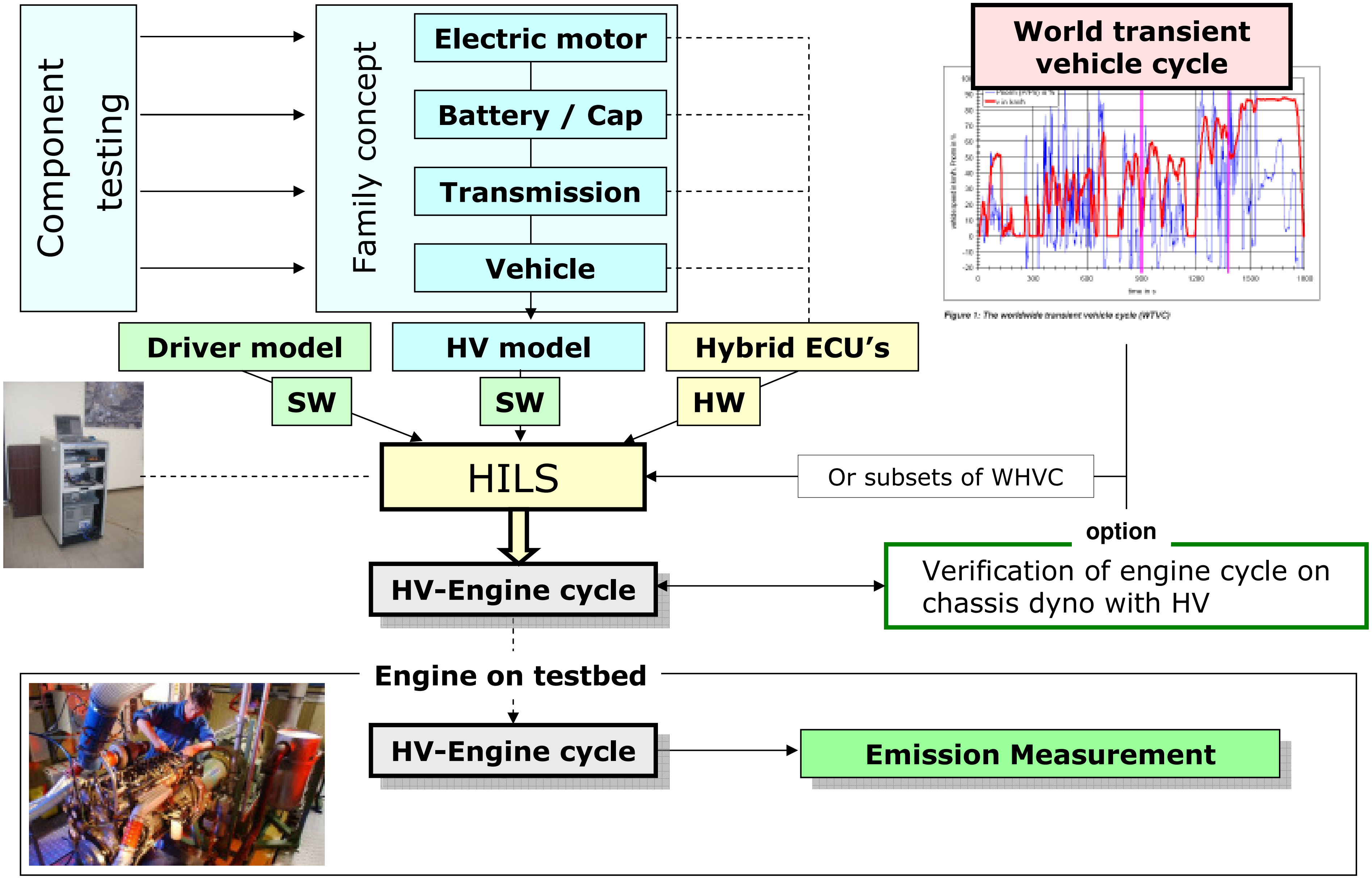


- Source **TRANS/WP29/GRPE/2001/2**

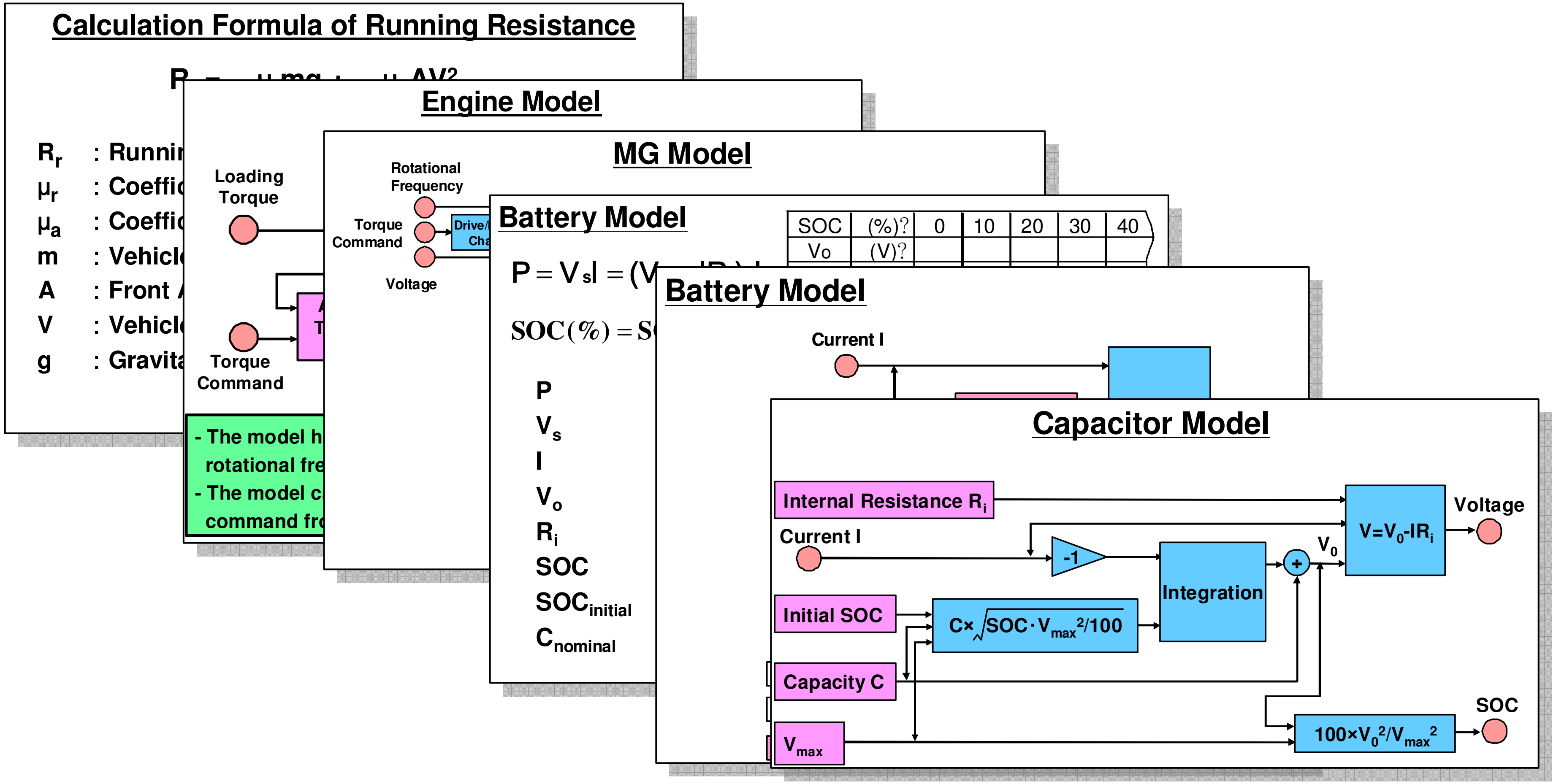
Basic approach



HILS-methodology

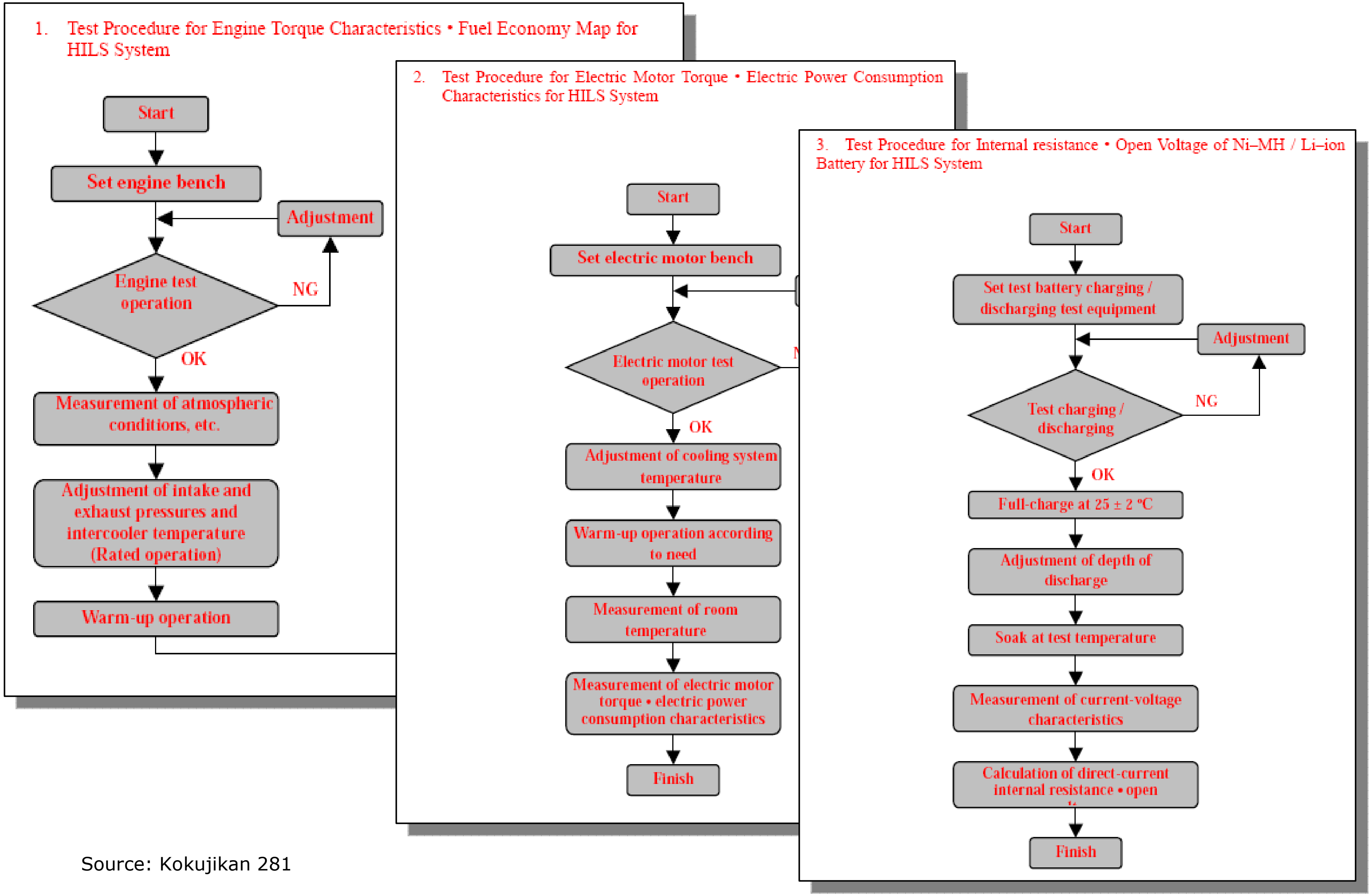


JARI: HEV-Models



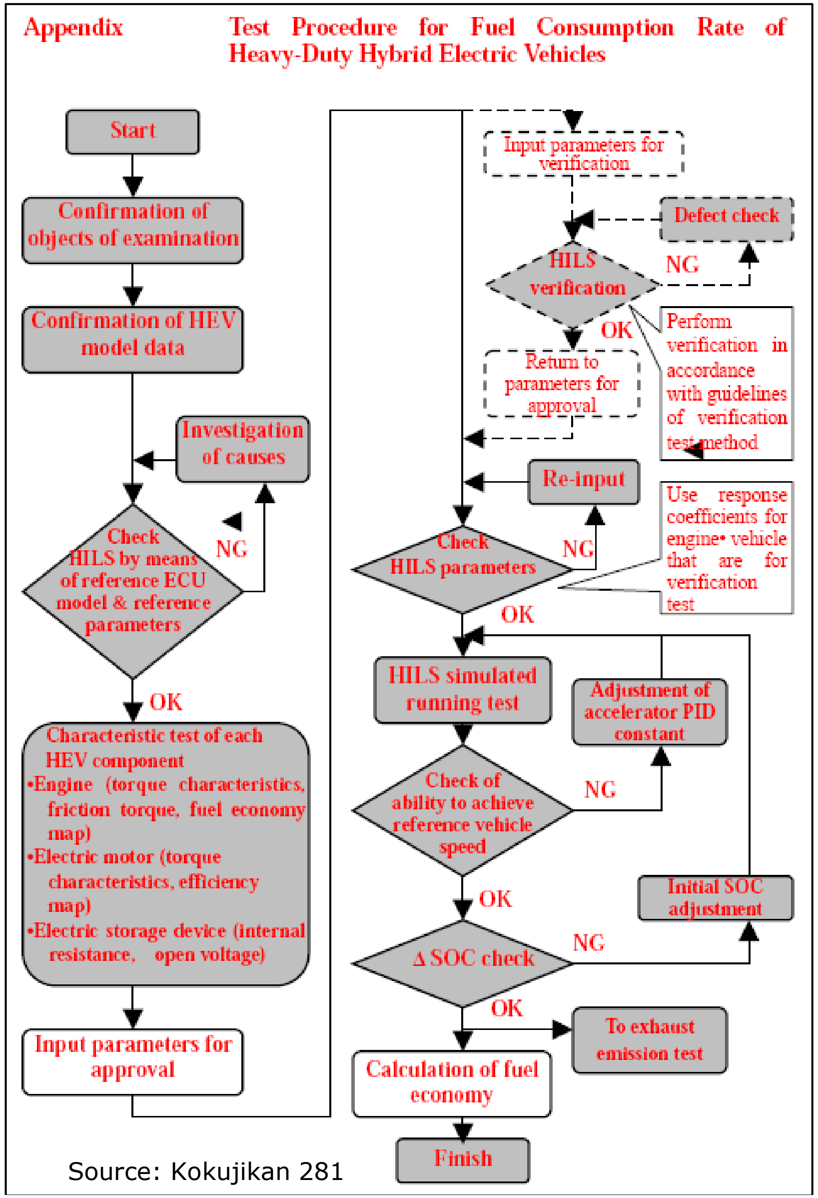
Source: JARI presentations

Test procedures engine, motor, battery

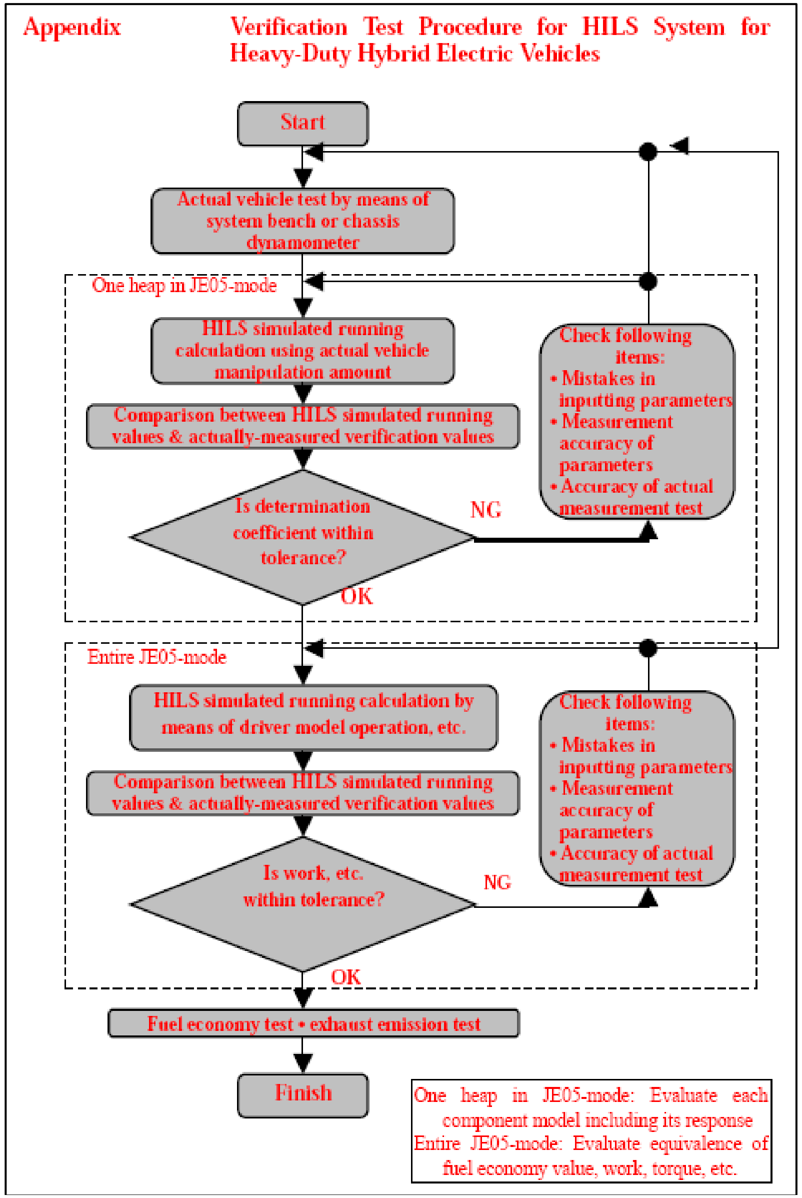


Source: Kokujikan 281

Test procedure FC, Emissions and verification

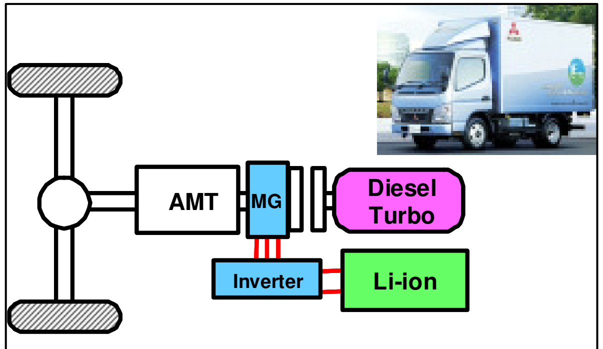


Source: Kokujikan 281

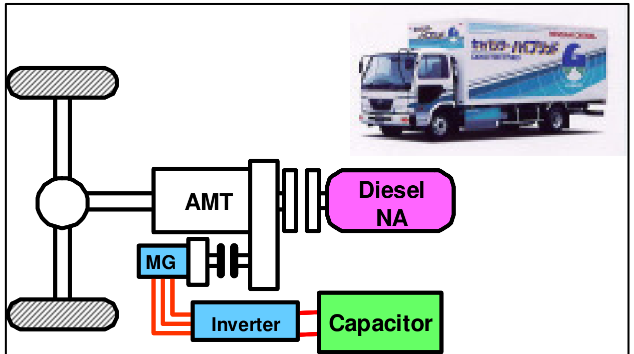


JARI: standardised HEV - models

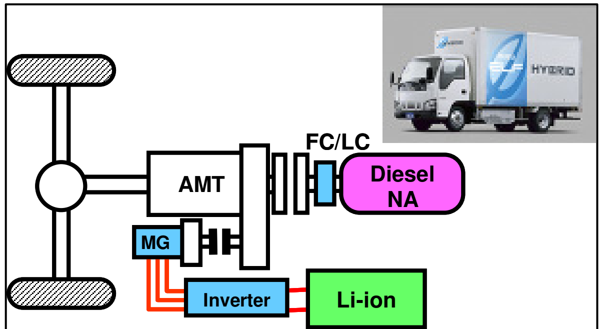
Parallel Hybrid



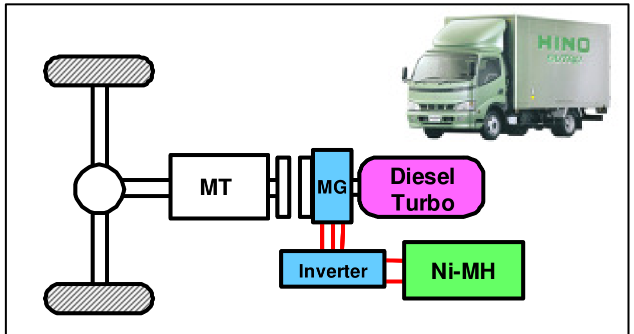
MG-TM Direct Connecting Type
(Vehicle A)?



PTO Use Type
(Vehicle B)?

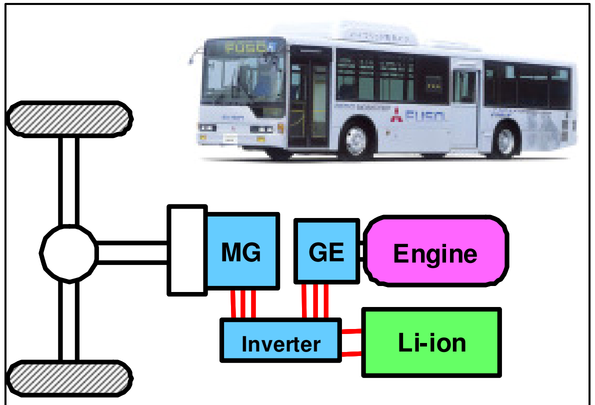


PTO Use Type with FC/LC
(Vehicle C)



MG-Engine Direct Connecting Type
(Vehicle D)?

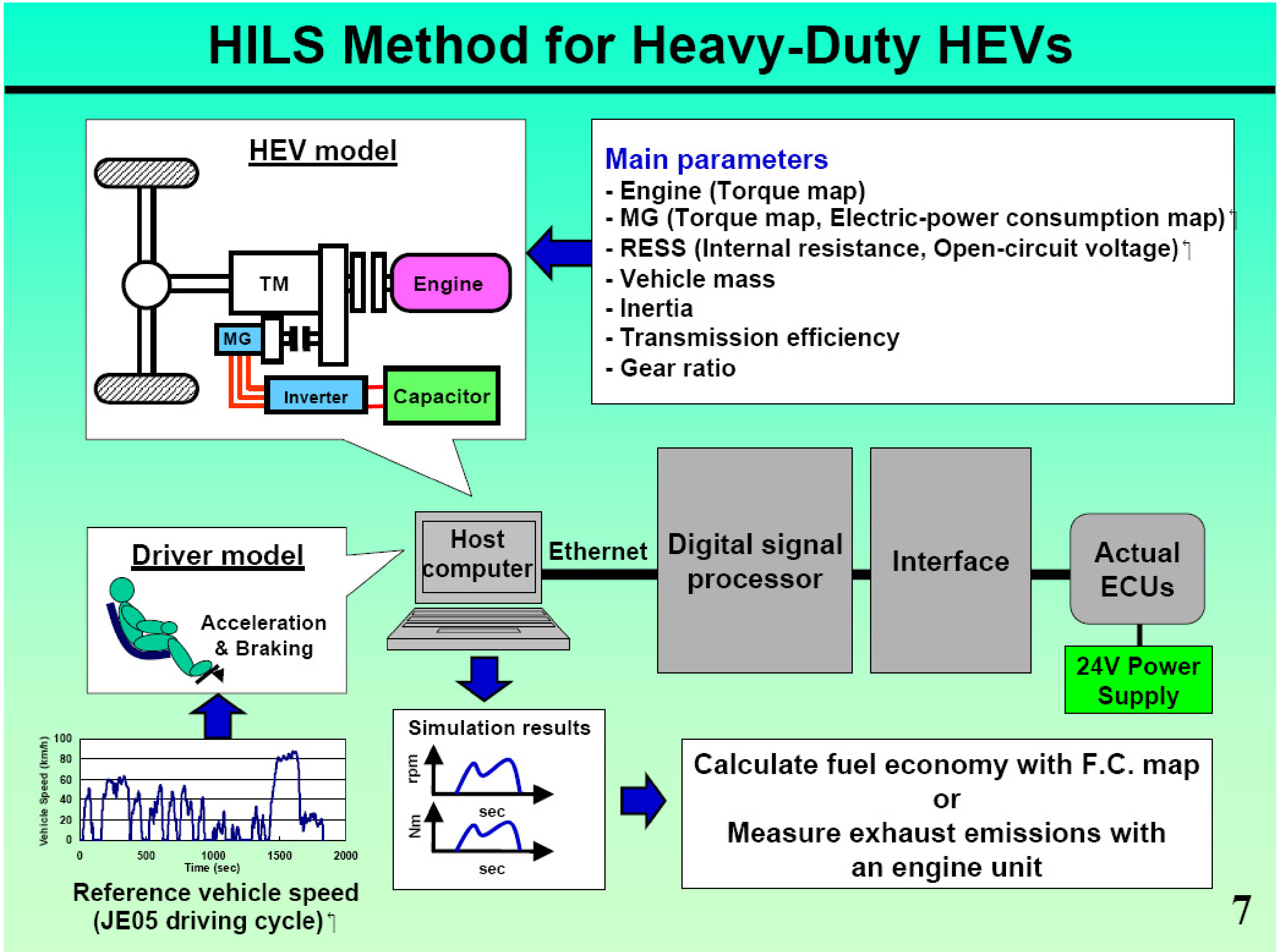
Serial Hybrid



Single Speed S-HEV
(Vehicle E)?

Source: JARI presentations

Japanese HILS system approach



Source: JARI presentations

JAMA / JARI HILS validation

- Evaluation of system bench test versus HILS
  - System bench test has too many limitations (types of hybrid systems) and inaccuracies
  - System bench test requires intensive resources
- With HILS method the engine can be tested in engine test-cell
  - Standard emission testing procedures
  - No additional resources for emission testing than usual
- HILS methodology verified in different steps
  - Rolling resistance air drag: coast down
  - Acceleration and braking
  - Overall evaluation with driver model
  - Over JE05 cycle …work
  - And fuel economy testing
  - With very good results

HILS - HW

HILS – HW

The HILS-hardware as seen at the demonstration at JARI.
The hardware is CRAMAS (Fujitsu Ten), the software from OnoSokki, no open source code, copyright issues
Currently the approx price of one system is Euro 160k

Tech. evaluation, issues

Issue	Potential solution	Comment
Durability, SOH	Introduction of DF‘s, in-use-conformity PEMS	investigation
Thermals	Electric systems only, specify and apply limitations and implement them into the models	
Auxiliaries	For emission certification not important	Details to be aligned with WHDC
Multi-ECU, distributed functionality	Install ‚CAN-Bus‘ in HILS HW, seems to be basically possible	Key requirement
Difficulty with HW-integrated ECU / SW	SILS would be alternative but bearing other risks	Validation required, IUC-PEMS
All types of gearboxes	Introduce new models for automatic transmissions	Just work
Cold start	Test the engine as in WHTC (cold and hot soak test)	
Cycle bypass potential	Requires verification, PEMS-ISC to be applied	
HILS code	must be open-sourced	Black box model is not acceptable in a certification procedure
HILS-HW sourcing	To establish specifications	Incl. calibration
HILS models public	Public description of models	
Heat recovery (exhaust)	Fitted on engine at certification or by simulation	Possible extension of HILS

Source: ACEA TF-HILS final report

HILS as developed by JAMA/JARI

Base documents

- SAE paper "Development of a fuel economy and emission test method with HILS for HD HEV's" 2008-01-1318
- Kokujikan No. 281 of March 16, 2007:

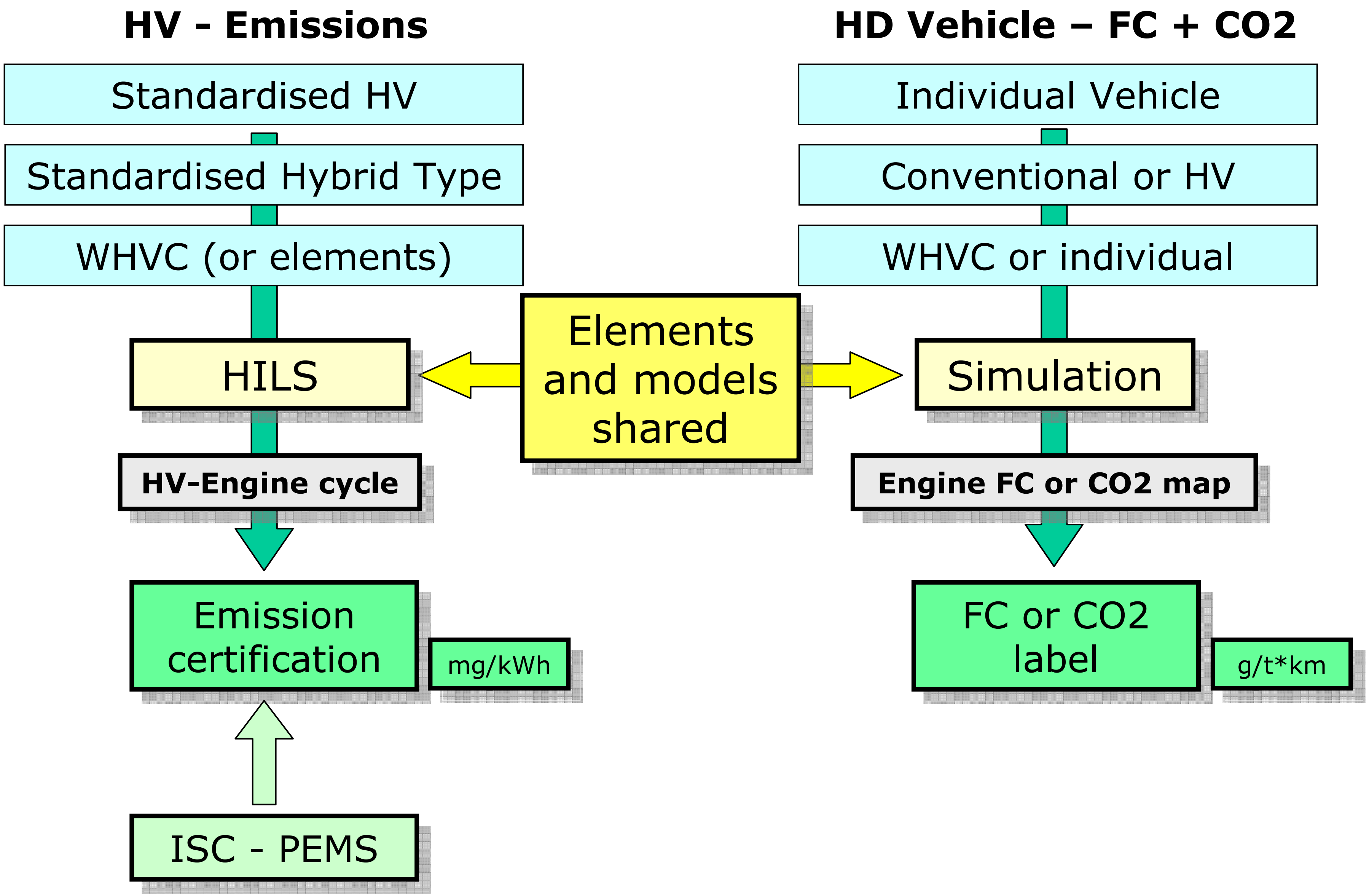
  TEST PROCEDURE FOR FUEL CONSUMPTION RATE AND EXHAUST EMISSIONS OF HEAVY-DUTY HYBRID ELECTRIC VEHICLES USING HARDWARE-IN-THE-LOOP SIMULATOR SYSTEM
- Kokujikan No. 282 of March 16, 2007

  TEST PROCEDURE FOR HILS SYSTEM PROVISIONAL VERIFICATION FOR HEAVY-DUTY HYBRID ELECTRIC VEHICLES

Fuel consumption / CO_2

- HILS is proposed as emission certification test procedure along the same lines as WHDC → g/kWh emissions for a standardised cycle (WHVC) and standardised vehicle (family concept), all other Euro VI requirements apply
- ISC will check emission performance in real service
- HD-HV CO_2 must be based on vehicle mission and load → elements of HILS in combination with individual vehicle specs, mission and load can be used for CO_2 qualification

Emissions - FC + CO2



Other issues, challenges

- OCE, NTE to be adapted
- Emission test cycles with engine standstill periods (testbed and PEMS) → test equipment and control, protocols may need updating

Summary

HIL-Simulation is the most cost-effective approach for emission certification of dedicated engines for HD-HV

WHVC

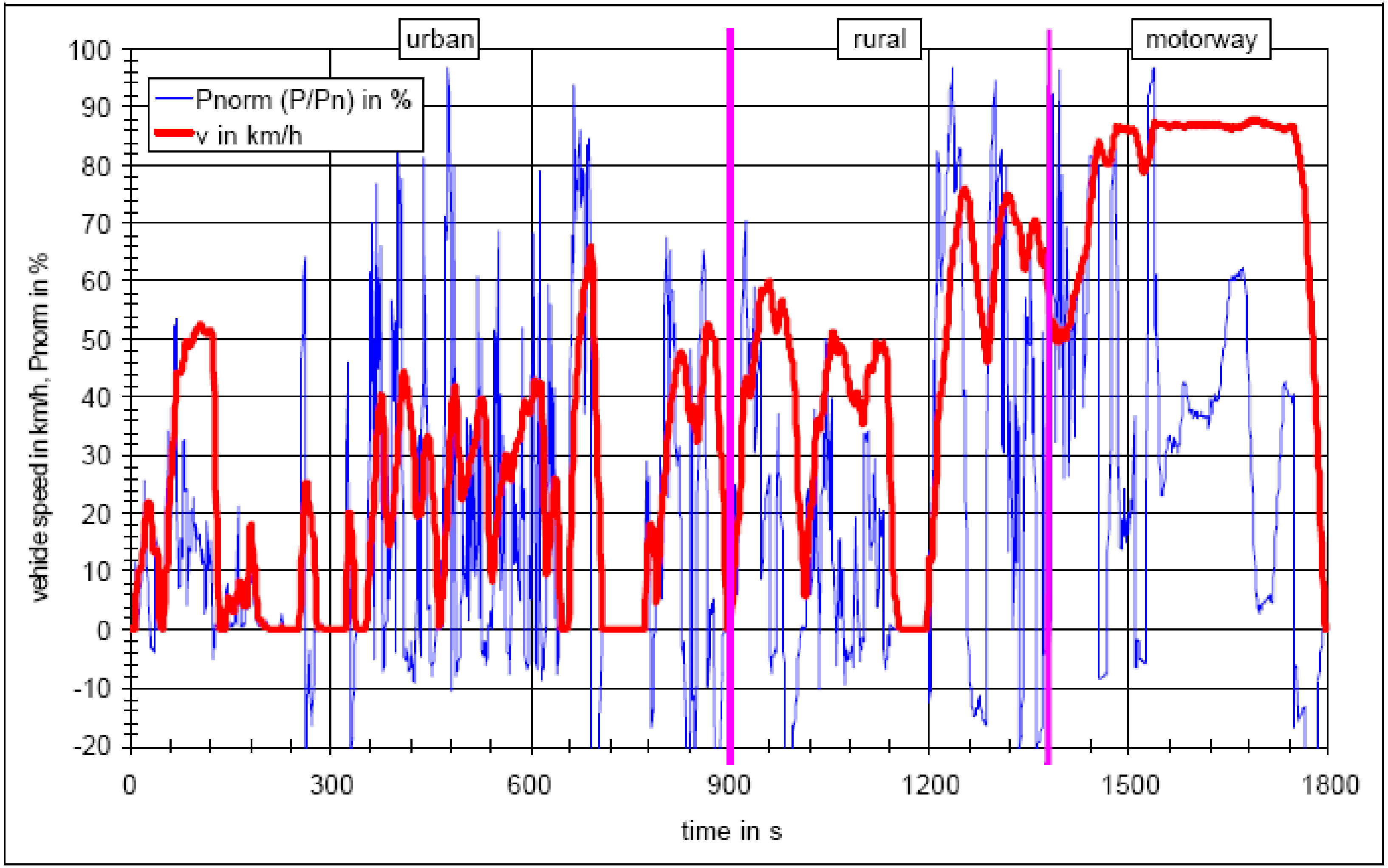
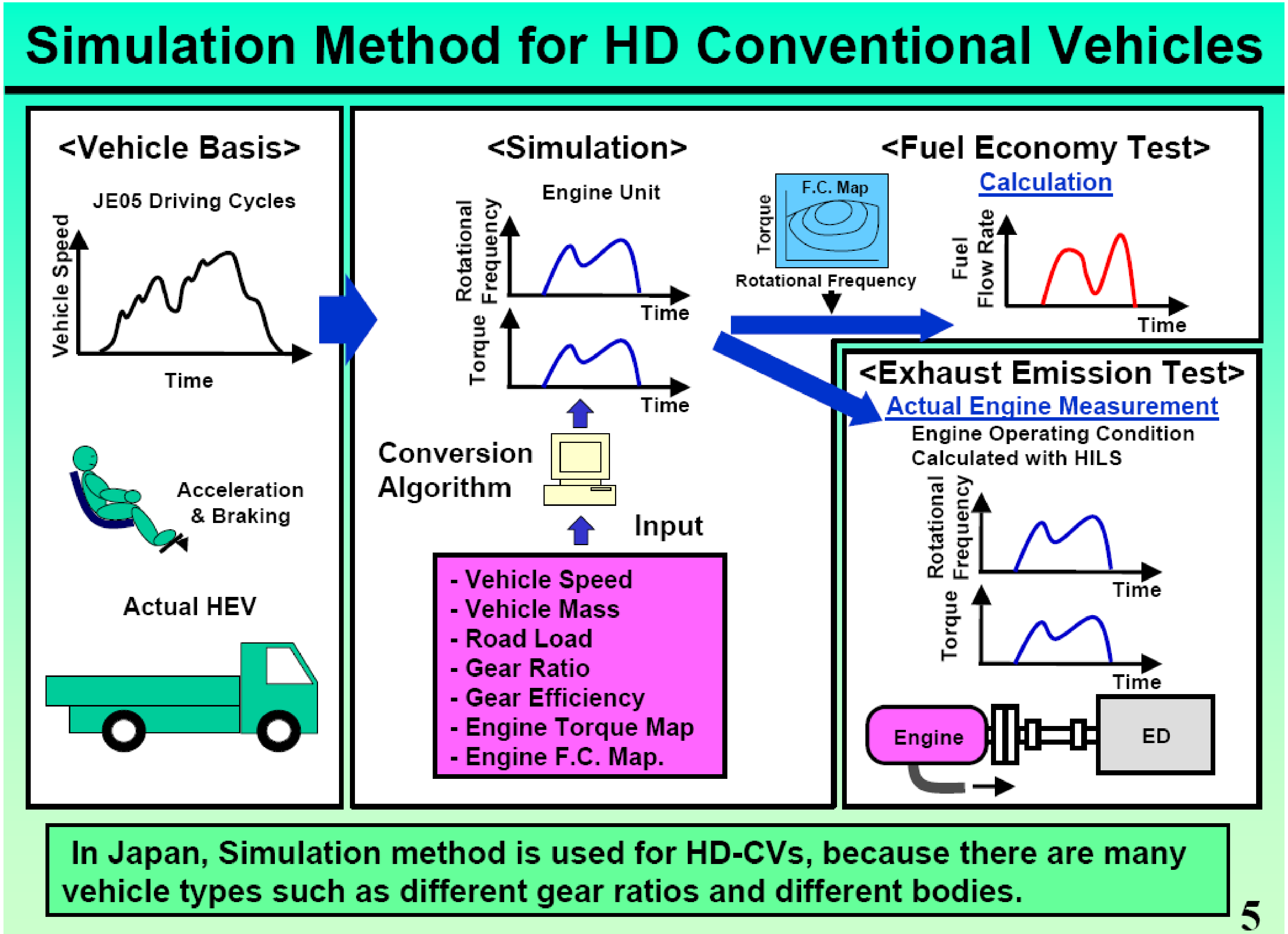


Figure 1: The worldwide transient vehicle cycle (WTVC)

Conventional HD trucks – fuel economy / emissions Japan



Japan Standard Vehicle Specification

standard vehicle specification by MLIT for exhaust/ gas

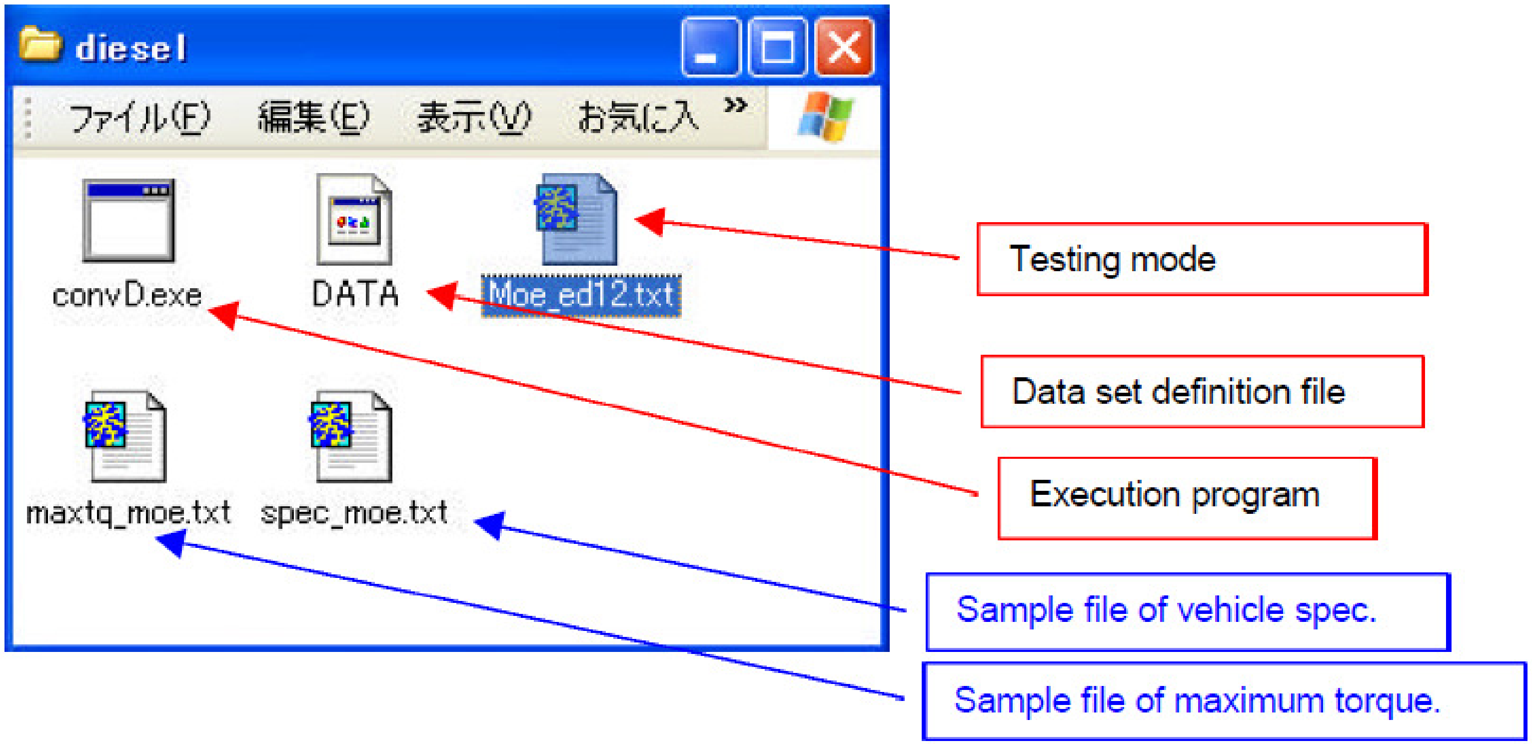
truck/ tructor category			bus category		fuel	empty vehicle mass	maximum payload	number of persons	test vehicle mass	tire dynamic radius	overall hight	overall width	transmission gear ratio							diff gear ratio
category NO	vehicle mass range GVW/ GCW(kg)	pay load range	category NO	vehicle mass range GVW(kg)		(kg)	(kg)		(kg)	(m)	(m)	(m)	1st	2nd	3rd	4th	5th	6th	7th	
T1	3.5t<&≦7.5t	≦1.5t	-	—	D・LPG・CNG	1957	1490	3	2757.0	0.313	1.982	1.695	5.076	2.713	1.529	1.000	0.795			4.615
					G・LPG・CNG	1659	1458	3	2443.0	0.303	1.975	1.695	4.942	2.908	1.568	1.000	0.834			4.477
T2		1.5t<	B1	3.5t<&≦6t	D・LPG・CNG	2482	2396	3	3735.0	0.343	2.106	1.780	5.080	2.816	1.587	1.000	0.741			5.275
					G・LPG・CNG	2259	2016	3	3322.0	0.327	2.052	1.722	5.089	2.773	1.577	1.000	0.777			6.051
T3	7.5t<&≦8t	—	B2	6t<&≦8t	G・D・LP G・CNG	3543	4275	2	5735.5	0.388	2.454	2.235	6.350	3.876	2.301	1.423	1.000	0.762		4.771
T4	8t<&≦16t	—	B3	8t<&≦16t	G・D・LP G・CNG	4527	7737	2	8450.5	0.469	2.617	2.374	6.416	4.096	2.385	1.475	1.000	0.760		5.208
T5	16t<&≦20t	—	B4	16t<&≦20t	G・D・LP G・CNG	8688	11089	2	14287.5	0.502	3.049	2.490	6.331	4.224	2.410	1.486	1.000	0.763	0.612	6.309
T6	20t<&≦25t	—	B5	20t<	G・D・LP G・CNG	8765	15530	2	16585.0	0.473	2.934	2.490	6.304	4.170	2.393	1.456	1.000	0.752	0.604	5.102
T7	25t<	—	-	—	G・D・LP G・CNG	12120	24974	2	24662.0	0.507	2.961	2.490	6.147	4.000	2.281	1.434	1.000	0.760	0.597	6.061

truck GVW=empty vehicle mass+maximum pay load+(number of persons) x 55kg

bus GVW=empty vehicle mass+(driver+number of passengers)x55kg

test vehicle mass=empty vehicle mass +maximum pay load/ 2+55kg

Engine Cycle Conversion Program



Example of Cycle Conversion

```
C:¥Documents and Settings¥stadashi¥デスクトップ¥diesel¥convDintel.exe
GVW    = 7860.00[kg]
W0     = 3400.00[kg], Wtest = 5630.00[kg]
Width =   2.230[m],  Height=   2.410[m], Tire radius=   0.388[m]
Crew =  2

Nidle =  550.00[rpm], Nrate = 2500.00[rpm], Nex  = 2700.00[rpm]
Nes   =  647.50[rpm], Nec   =  628.00[rpm]
MuAir =  0.015237 [kgf/(km/h)^2], MuRoll =  0.008256 [kgf/kg]

Number of gear =  6
gear    ratio  efficiency  torq margin    DW[kg]
  1:     6.098      0.950       2.400     4030.93161
  2:     3.858      0.950       2.400     1756.18473
  3:     2.340      0.950       1.700      796.51120
  4:     1.422      0.950       1.600      444.25257
  5:     1.000      0.980       1.600      340.00000
  6:     0.761      0.950       1.600      297.07034
fin:     3.900      0.950

Type filename for output : outmoe.txt_
```

Example of Data Output

Vehicle Cycle → Engine Cycle

time (s)	Vtarget (km/h)	Vreal(km/h)	Ne (rpm)	Te (N-m)	n_norm (%)	T_norm (%)	shift
0	0	0	500.0	0.0	0	0	0
1	0	0	500.0	0.0	0	0	0
2	0	0	500.0	0.0	0	0	0
3	0	0	500.0	0.0	0	0	0
4	0	0	500.0	0.0	0	0	0
5	0	0	500.0	0.0	0	0	0
6	0	0	500.0	0.0	0	0	0
7	0	0	500.0	0.0	0	0	0
8	0	0	500.0	0.0	0	0	0
9	0	0	500.0	0.0	0	0	0
10	0	0	500.0	0.0	0	0	0
11	0	0	500.0	0.0	0	0	0
12	0	0	500.0	0.0	0	0	0
13	0	0	500.0	0.0	0	0	0
14	0	0	500.0	0.0	0	0	0
15	0	0	500.0	0.0	0	0	0
16	0	0	500.0	0.0	0	0	0
17	0	0	500.0	0.0	0	0	0
18	0	0	500.0	0.0	0	0	0
19	0	0	500.0	0.0	0	0	0
20	0	0	500.0	0.0	0	0	0
21	0	0	500.0	0.0	0	0	0
22	0	0	500.0	0.0	0	0	0
23	0	0	500.0	0.0	0	0	0
24	0	0	500.0	0.0	0	0	0
25	4.19	4.19	562.5	952.1	5	88.73	2
26	8.32	8.32	770.3	939.2	21.63	61.32	2
27	12.33	12.33	1141.6	913.4	51.33	50.64	2
28	16.05	16.05	1486.0	850.3	78.88	49.46	2
29	18.74	18.74	1020.3	864.8	41.62	47.56	3
30	20.28	20.28	1104.1	520.7	48.33	28.78	3