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Overview of Open Source Models

Informal Working Group on Heavy Duty Hybrids
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JASIC

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1. Background

Japan has been working for the full open source of the standardized HEV model in Japan for the purpose of international harmonization of HILS test procedure.

Nevertheless, current HILS Certification Model used in Japan can not be provided due to the intellectual property right.

To get over this difficulty, JAMA/JARI is now under development of another model which can be disclosed. The model which we release today is a rigid model for parallel hybrid vehicle, which was reported at #3 HDH-IG.

As explained above, this is not the same model which is currently certified as HILS test procedure in Japan, however, the accuracy is almost verified by experts from HEV WG of JAMA.

We have also started the development of fluid coupling model and torque converter model. and the verification is also now underway, with a target of receiving approvals as HILS test procedure in Japan during fiscal year 2012.

We are ready to assist and support the research laboratories effort in member countries of HDH-IG for their operation of the model if required.

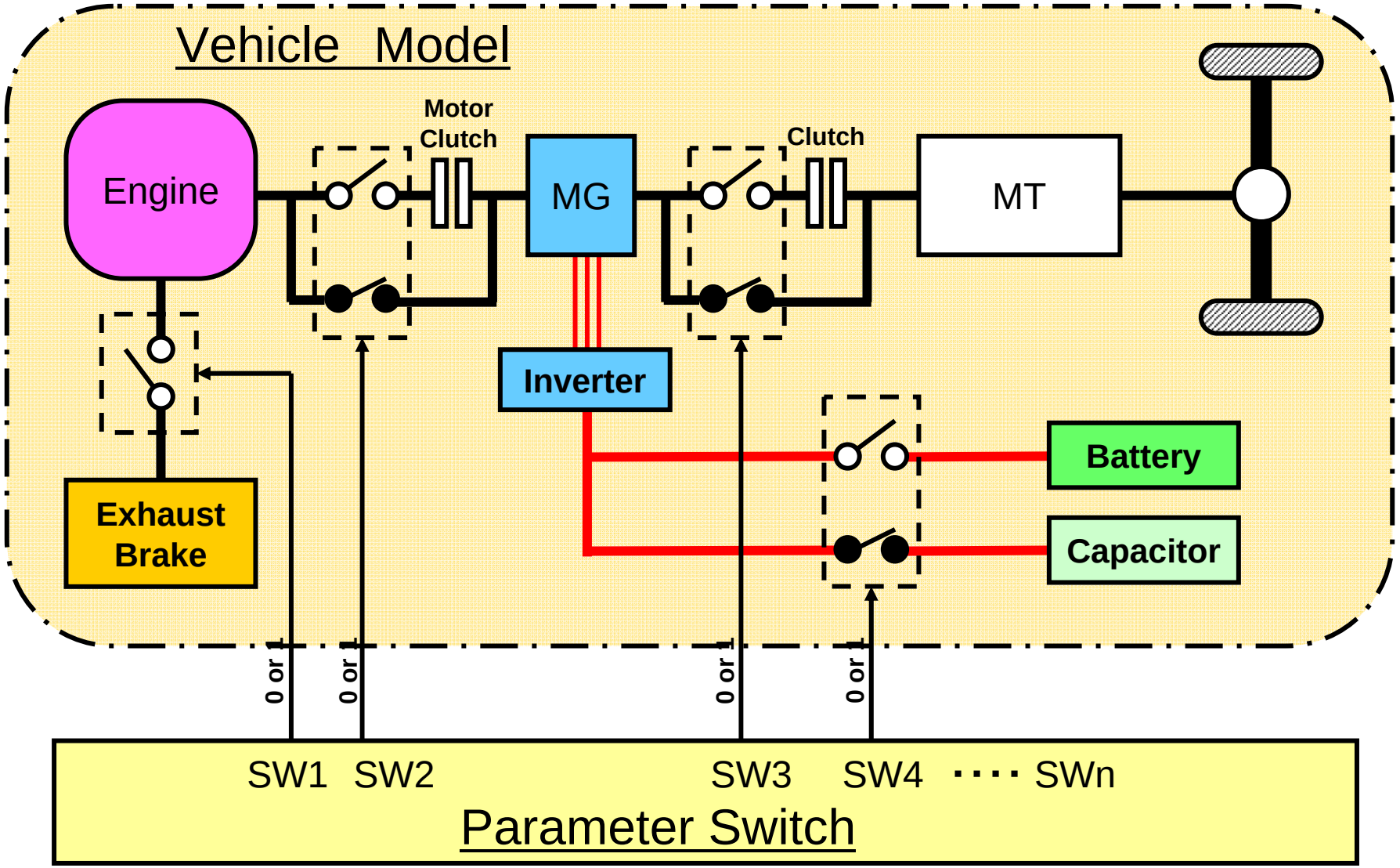
2. Open Source Model: Concepts

➢The model can apply to various HEVs

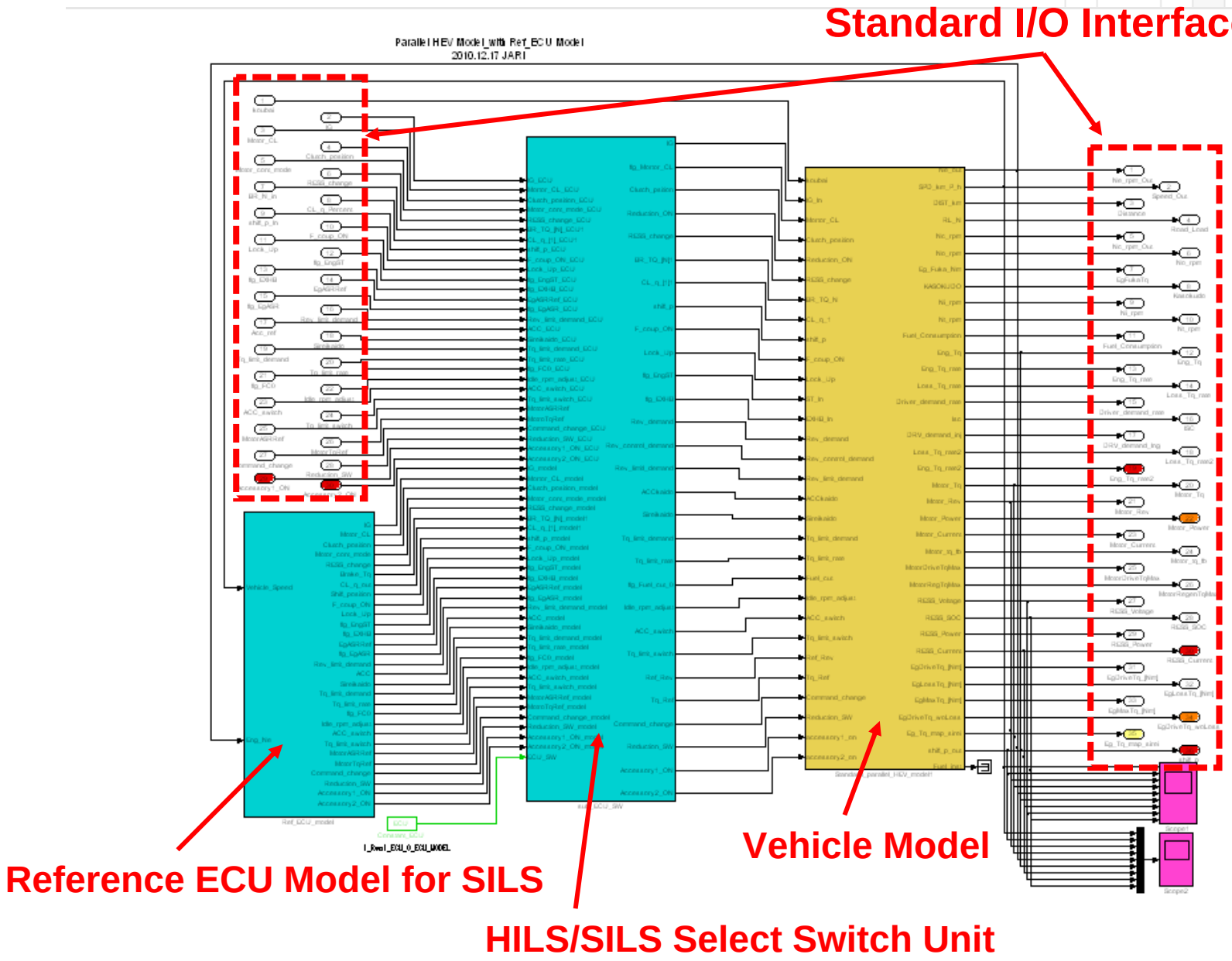
- Common signals to be defined for controlling HEVs
  => Standard I/O (inlet/outlet) interface
- Easy application to various HEVs
  => Parameter switches
- Parameters can reflect actual conditions
  => The reflection from actual hybrid component tests
- No limitation on the actual ECU (Hybrid electronic control unit)
  => Manufacture‘s interface model
- DSP (Digital Signal Processor) -free model
  => Possible to verify DSP performance by using SILS
- Prevention against illegal modification
  => Mandatory to verify the accuracy of HILS result by comparing with actual HEV test result

3. Open source model: fundamental structure(1)

- Parameter switches make model apply to various HEVs.



3. Open source model: fundamental structure(2)



4. Vehicle Model: Overview

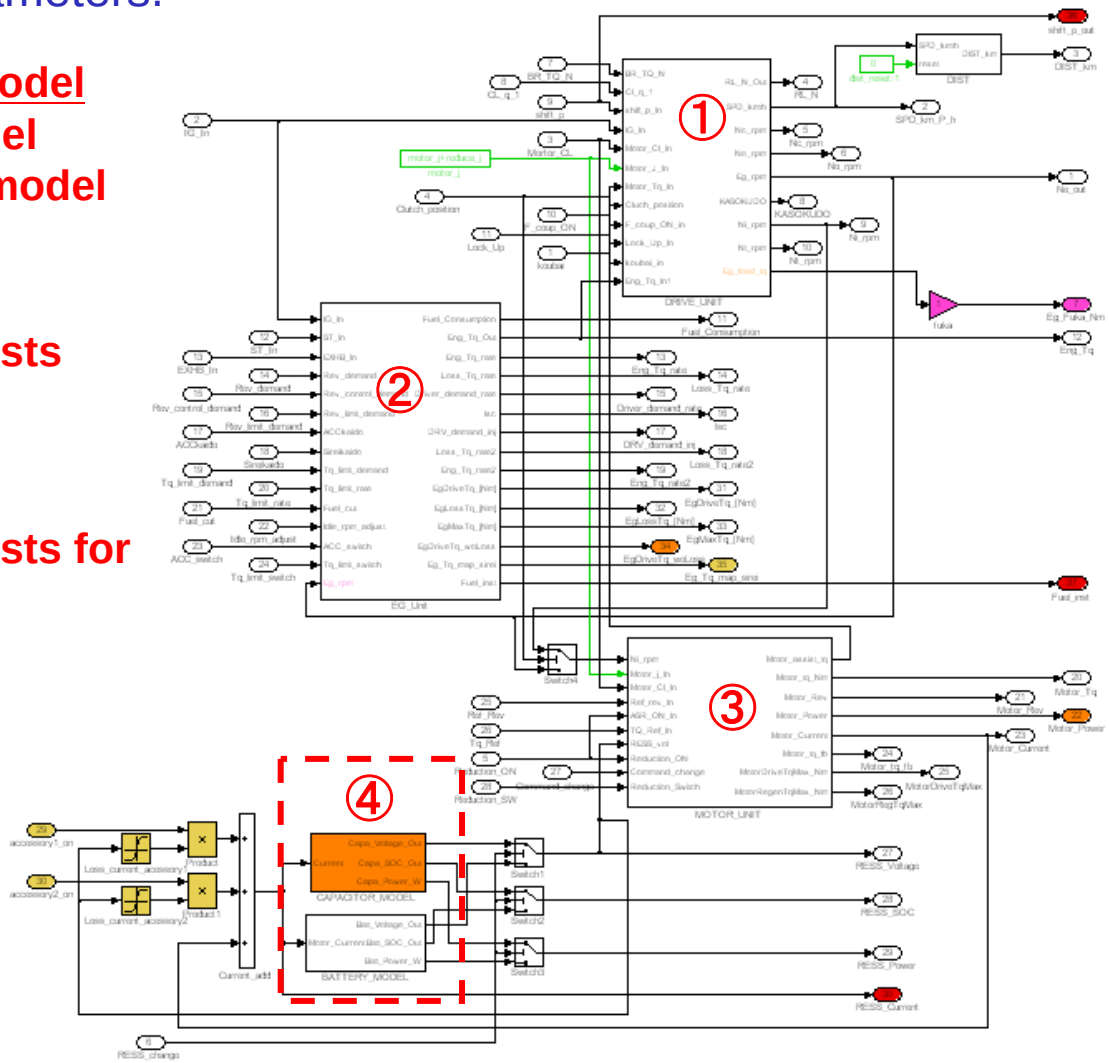
- Each model is built based on physical formulas
- Results of each component test (engine, electric motor ,battery) and factors of a vehicle as parameters.

① Vehicle / Power Train System Model
Include: - Running resistance model
- Transmission • vehicle model
- Clutch model

② Engine Model
Include: Results of performance tests for engines

③ Electric Motor Model
Include: Results of performance tests for electric motors

④ Rechargeable Energy Storage System (RESS) Model
Include:
- Battery model
- Capacitor model
- RESS performance test results

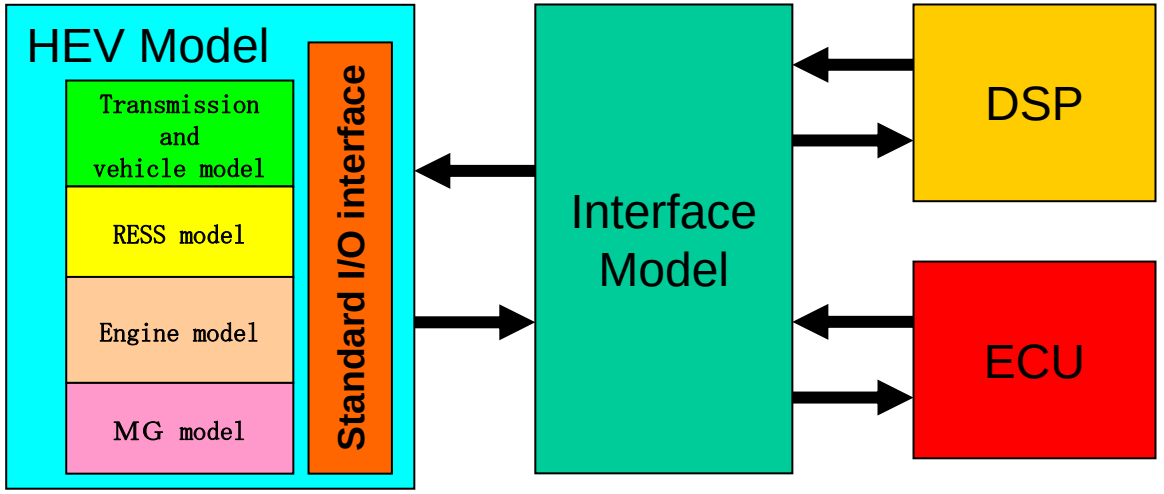


5. Interface model

Each manufacturer is allowed to create its own interface model to connect its ECU

The purpose of the interface model is
- to convert physical quantities of ECU electric signals to fit on the open source model calculations.
- to generate dummy signals if necessary to prevent vehicle fail.
- to convert some ECU signals necessary for calculations if needed.

It is mandatory to verify the accuracy of HILS result by comparing with actual HEV test result for verifying the interface model.
So it is impossible to create illegally interface model.



6. HILS Verification

Purpose

To verify the reproducibility for the behavior of the actual vehicle (or system).
For this purpose, following two verifications are developed.

1. Verification of correlation within a short-period vehicle operation

A small trip during urban driving part of Japanese JE05 test cycle. The cycle include start-acceleration-gearshift-deceleration-stop.
The correlation between the HILS calculation results and the actual vehicle (or system) operation are examined for the following items.

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

Note: This verification clarifies whether the model reproduces the behavior of the each hybrid segment by using the actual accelerating/braking pedal signals as input into HILS.
The difference caused by the calculation error does occur and accumulate as the operation period increases, and so it is not realistic to guarantee the correlation using long-period cycle because of the accumulation of the calculation error.
Therefore the correlation check using short-period test cycle is settled.

6. HILS Verification

2. Verification of correlation for the load and fuel efficiency of whole test cycle

To check whether the HILS calculation reproduces the actual vehicle (or system) throughout the long-period operation cycle, including several patterns of acceleration, deceleration. Total engine work and fuel consumption during the cycle are verified.

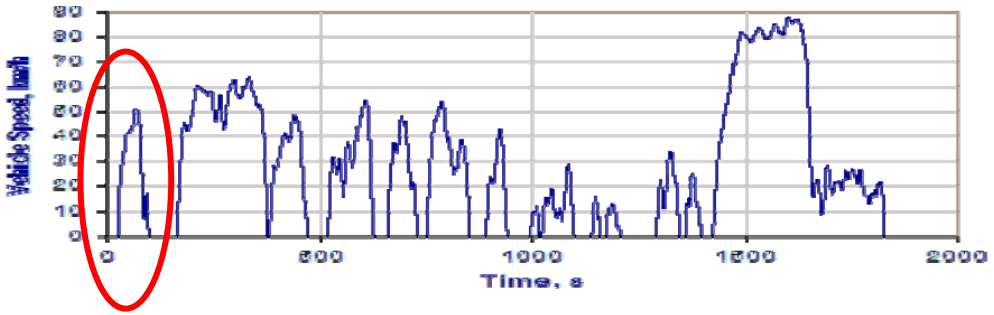
Note; This comparison of the load within the whole cycle does not guarantee that the behavior of each segment during the calculation process properly reproduces the actual vehicle (or system). The combination of the short-period verification for correlation and the whole cycle verification for the load assures the accuracy of HILS model.

The following slides show the overview of each step of verification.

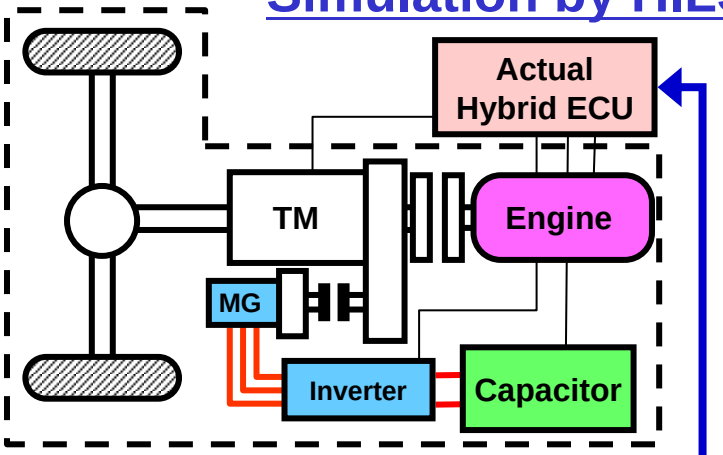
6. HILS Verification (1st Step)

Confirm Consistency: JE05 0-120sec

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



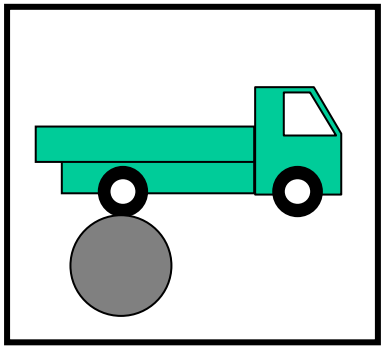
Simulation by HILS



Same Measured acceleration & braking signal

Result

Measured acceleration & braking signal



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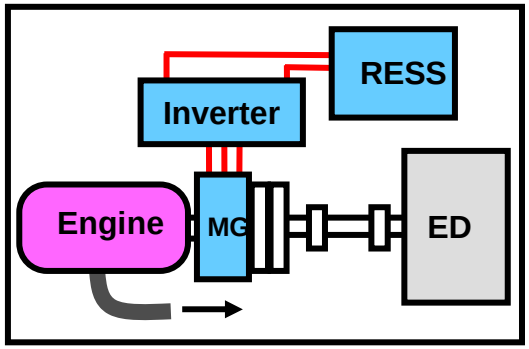


Result

Comparison

Real HEV Test on Chassis Dyno

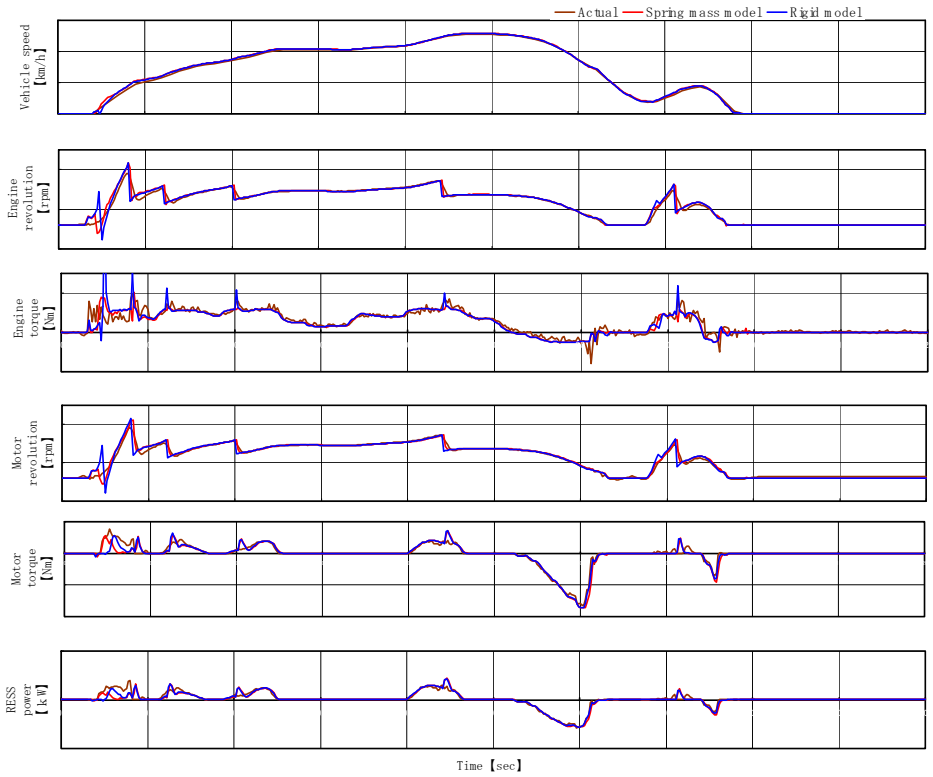
HEV Systems Test on Bench

6. HILS Verification (1st Step)

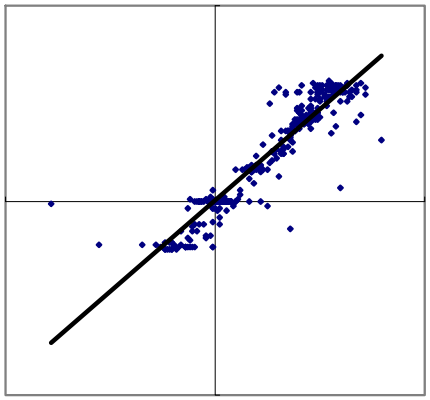
Sample Verification Results

- JE05 single trip verification: Comparing HILS Results with Actual Data

	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 ≤
Open source model	0.996	0.981	0.978	0.892	0.931	0.972



Open source model

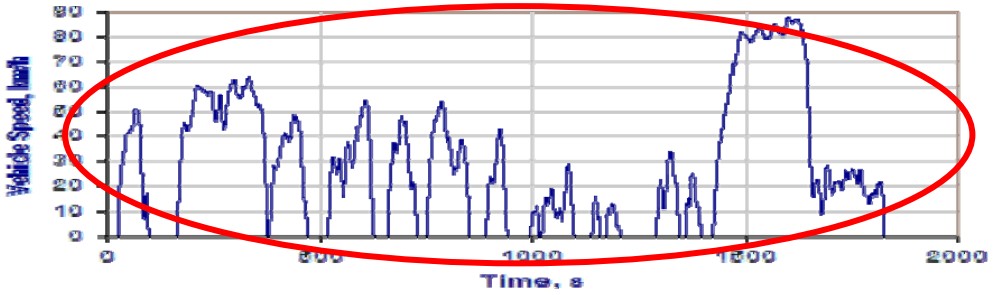


Engine Torque

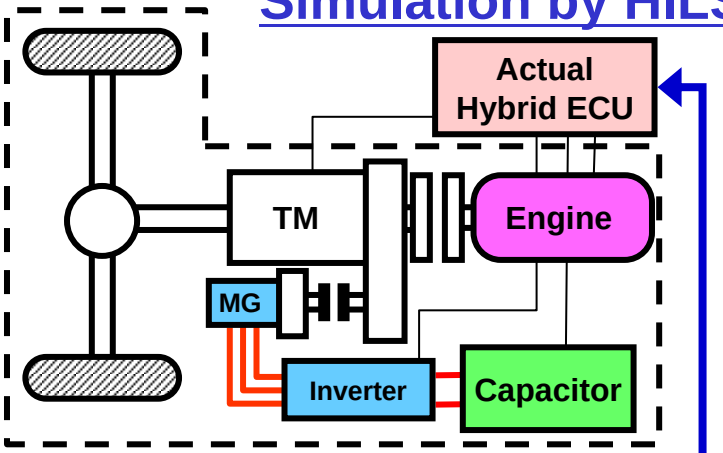
6. HILS Verification （2nd Step ）

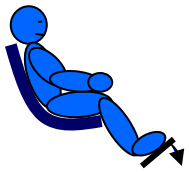
Confirm Consistency: JE05

Purpose: confirm the quality of vehicle model.



Simulation by HILS

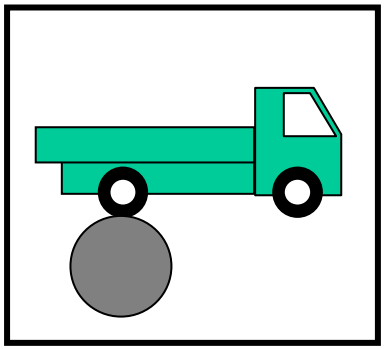




Driver model

Driver model out acceleration & braking signal

Result



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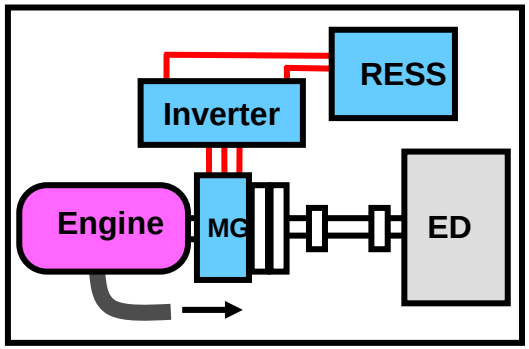


Result

Comparison

Real HEV Test on Chassis Dyno

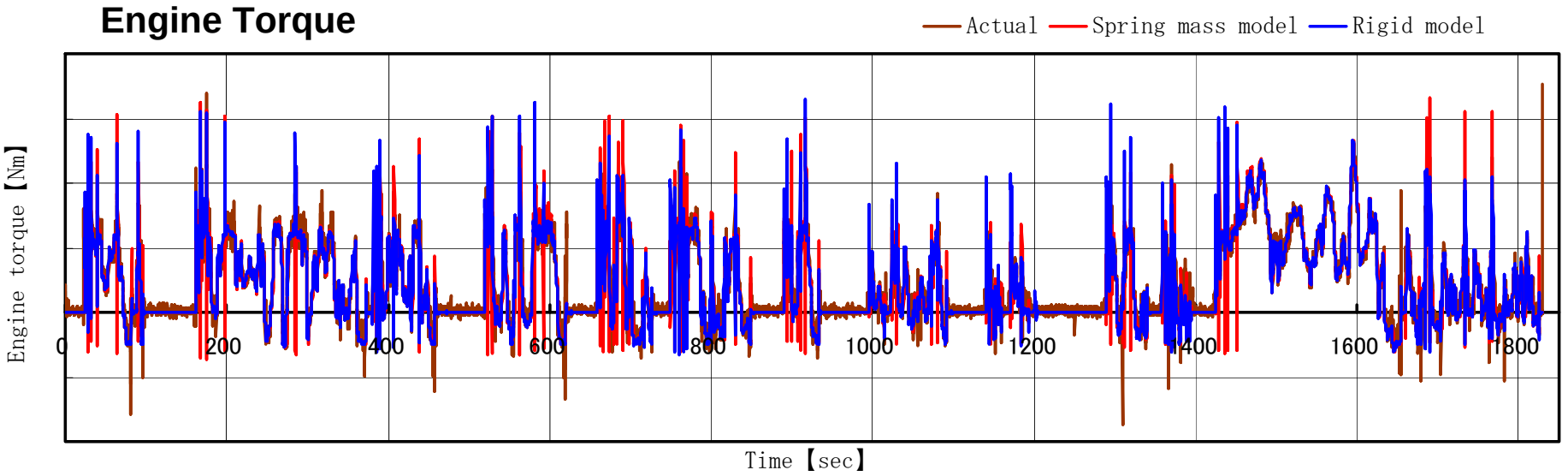
HEV Systems Test on Bench

6. HILS Verification (2nd Step)

Sample Verification Results

- Entire JE05 Results Verification: Comparing HILS Results with Actual Data

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
Open source model	0.994	0.895	1.003	0.999



7. System Verification before HILS test by SILS

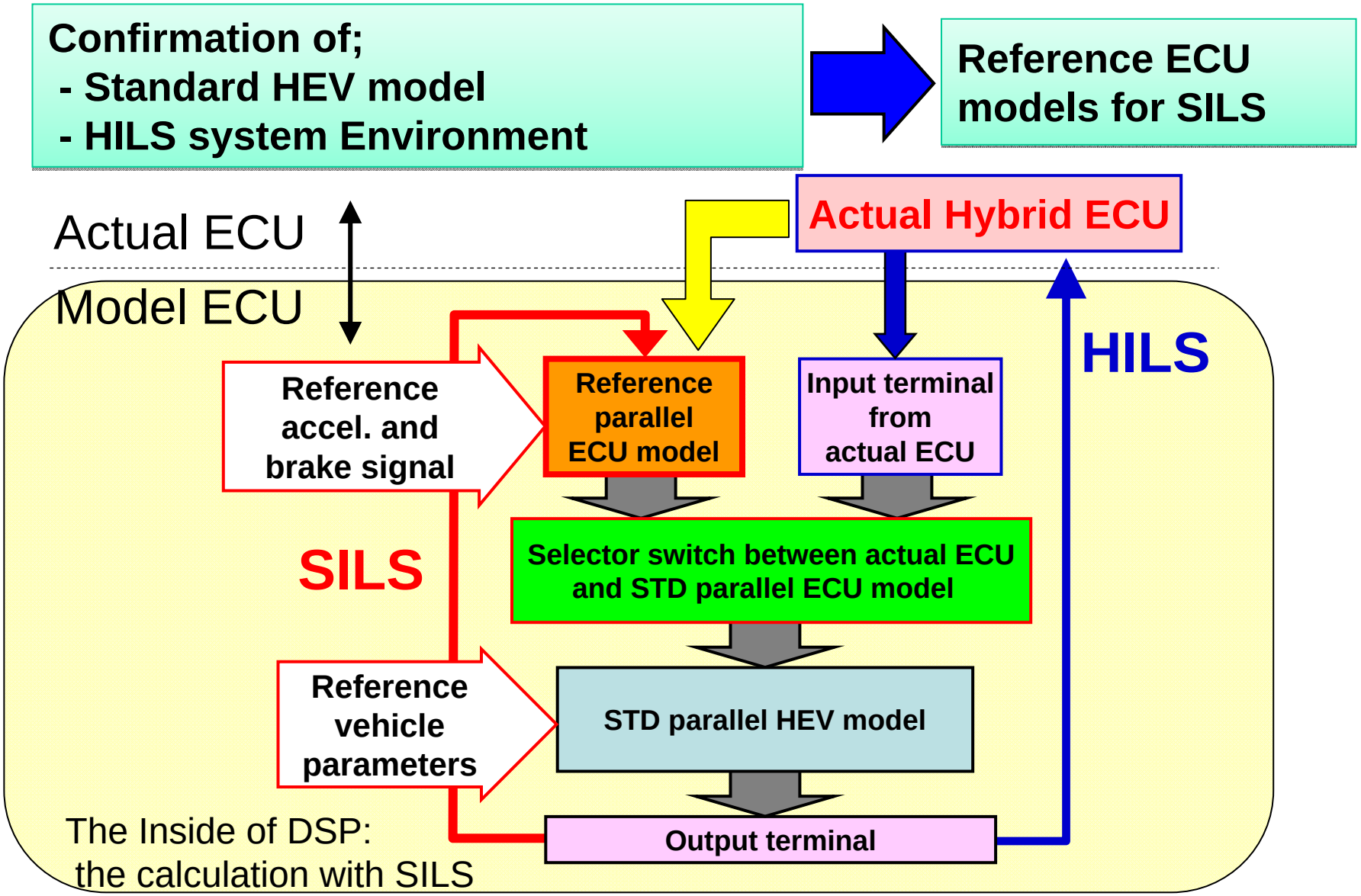
Purpose of SILS calculation

The HILS method itself does not restrict the behavior of DSP (hardware for HILS).
However, it is necessary to verify whether the DSP to be used is appropriate hardware for the type approval test of HEV.
For this purpose, we developed a testing method to verify the calculation performance within the DSP using the SILS model.

In this test, the calculation results by SILS of basic system is regarded as standard, and compare the results of DSP to be used, and check that the calculation performance of the DSP hardware is sufficient for the type approval test.

The following slides show the overview of SILS test.

7. SILS System Verification prior to HILS Testing

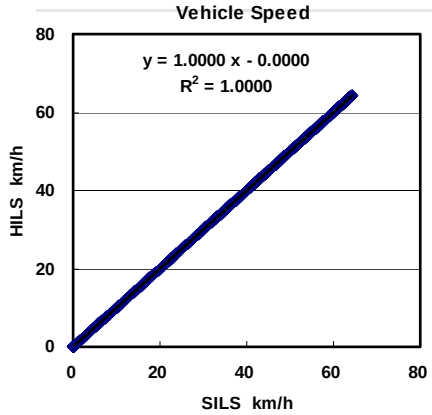


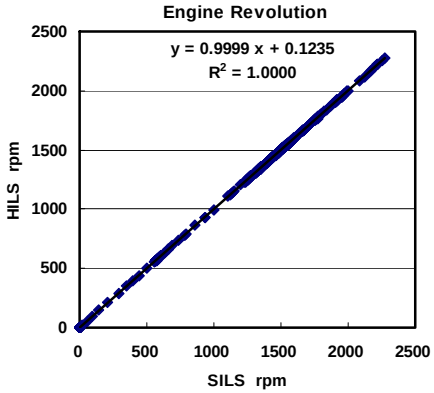
7. SILS System Verification prior to HILS Testing

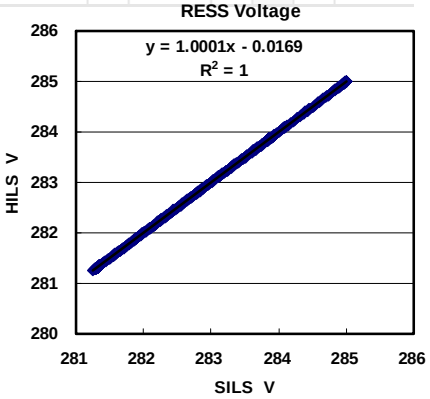
Example SILS Results for verifying HILS system.

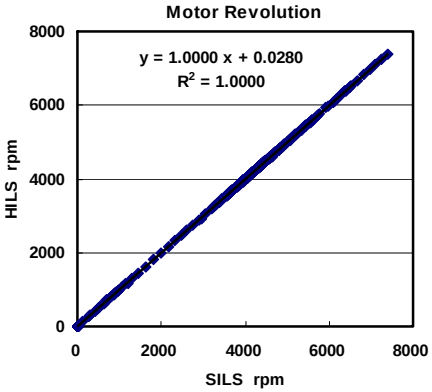
	Tolerance		
	Slope of the Regression Line	Y Intercept of the Regression Line	Coefficient of Determnation (r^2)
Verification items	0.9995 – 1.0005	+/- 0.05% and below of Maximum value	0.995 and above
Vehicle speed	1.0000	0.0000	1.0000
MG rev	1.0000	0.0280	1.0000
MG torque	1.0000	0.0006	1.0000
RESS voltage	1.0001	-0.0169	1.0000
RESS current	1.0000	-0.0071	1.0000
RESS SOC	0.9999	0.0031	1.0000
Engine rev	0.9999	0.1235	1.0000
Engine torque	1.0000	0.0129	1.0000

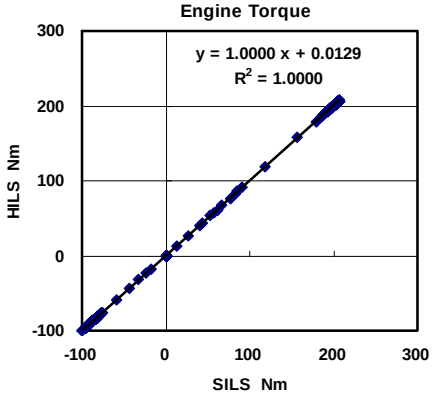
7. SILS System Verification prior to HILS Testing

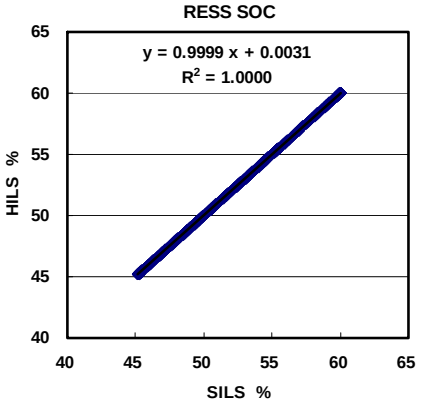


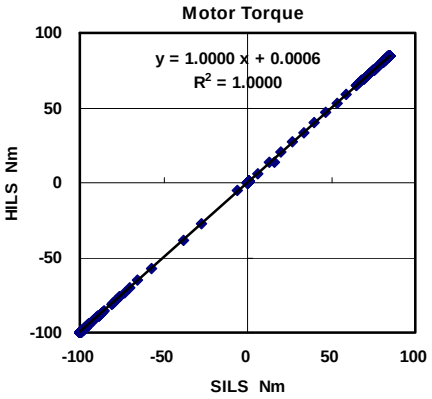


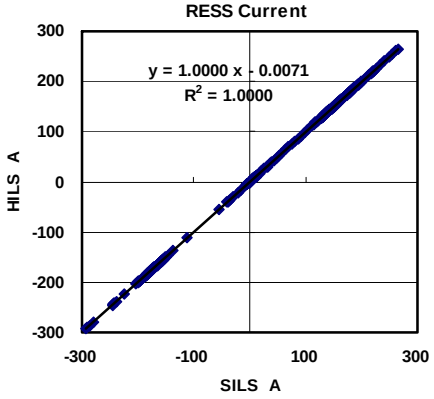












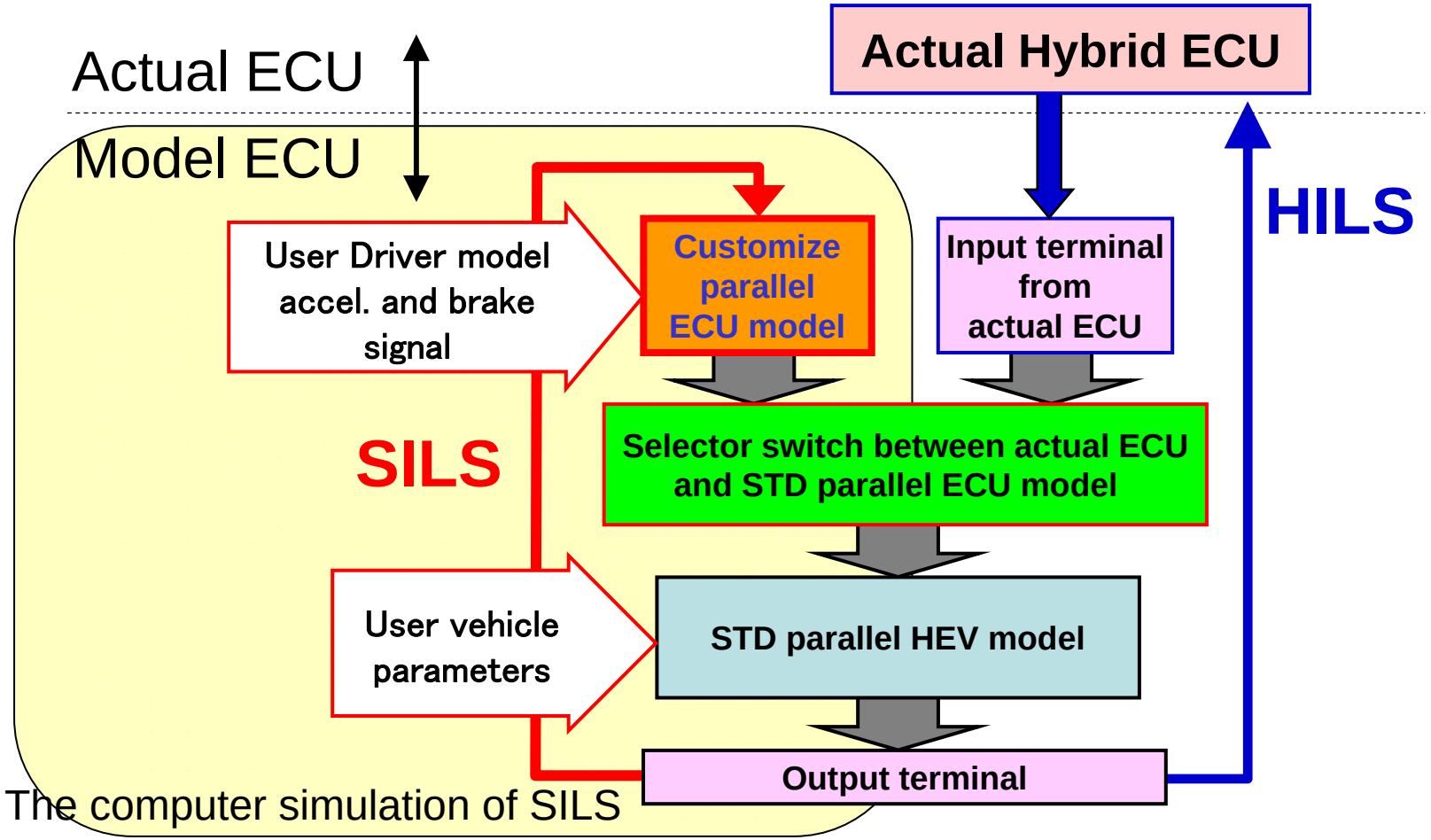
SILS Demonstration

END

Appendix

7. SILS System Verification prior to HILS Testing

In order to verify the open source model, by prepare a driver model and ECU model to be used in place of the standard using SILS, it is possible to conduct the running patterns needed using MATLAB/Simulink.



3. Interface Model: A Summary and an Example