ICCT / NESCCAF
Improving the Fuel Economy of Heavy Duty Fleets II

Session 2: Global Efforts to Encourage Heavy-Duty Vehicle Fuel Economy Improvements

Fuel Economy Test Procedure for Heavy-Duty Vehicles: Japanese Test Procedures

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7-42-27 Jindaiji-higashimachi, Chofu, Tokyo, 182-0012, JAPAN

20 February 2008

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- Fuel Economy Test Procedure for Heavy-Duty Vehicles
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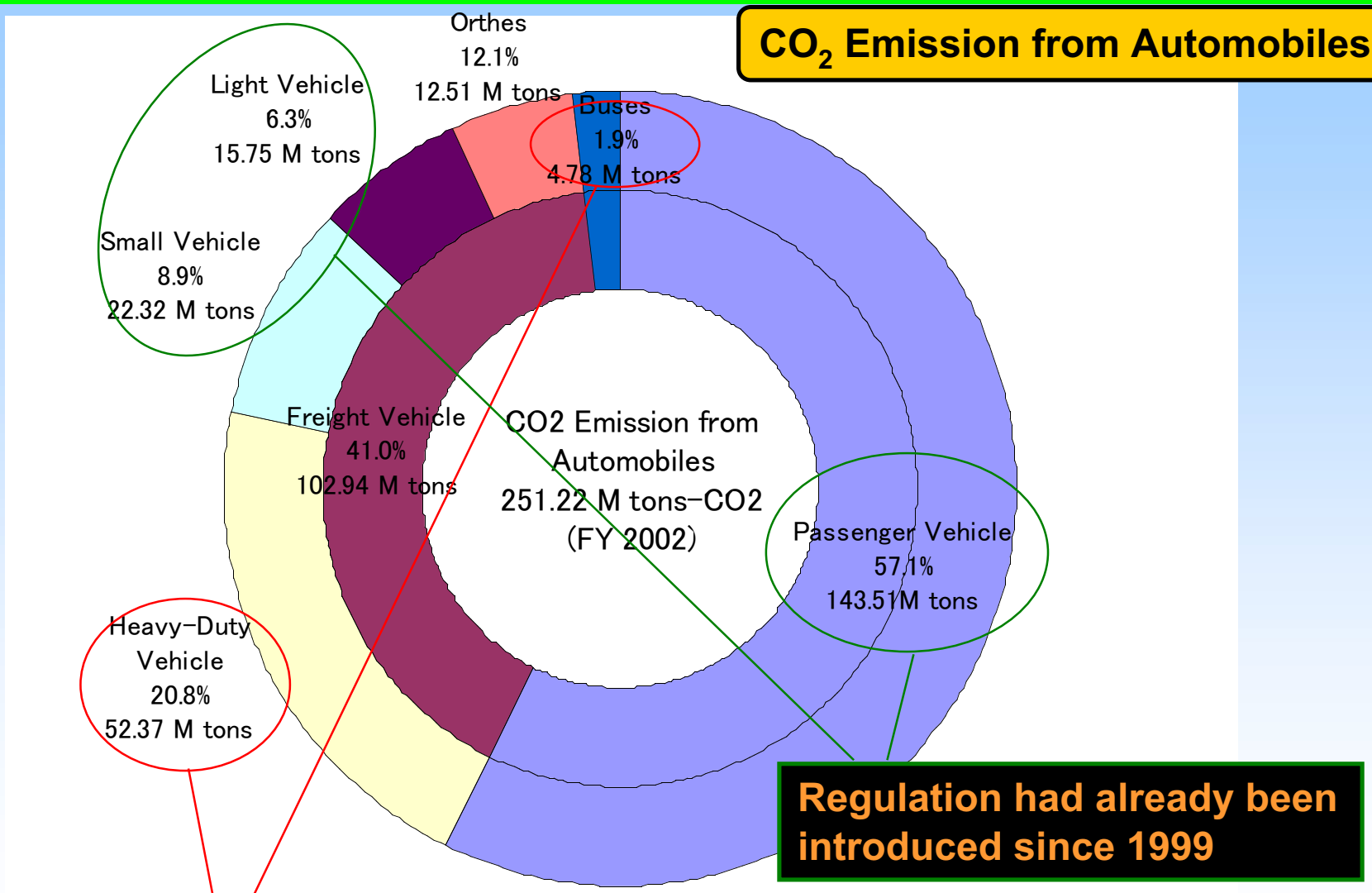
- **Background & Current Situation**

  CO_2 Emissions from Heavy-Duty Vehicles
  Top-Runner Standard for Fuel Economy

- **Fuel Economy Test Procedure for Heavy-Duty Vehicles**

- **Summary**

CO_2 Emissions from Heavy-Duty Vehicles



Fuel Economy Standard for HDVs

<Background>
About 25% of CO_2 from Automobiles were emitted from Heavy-Duty Vehicles.
→ "CO_2 Reduction = Fuel Economy Improvement" are needed.

Appropriate Measurement Method of Fuel Economy for Heavy-Duty Vehicles was developed.

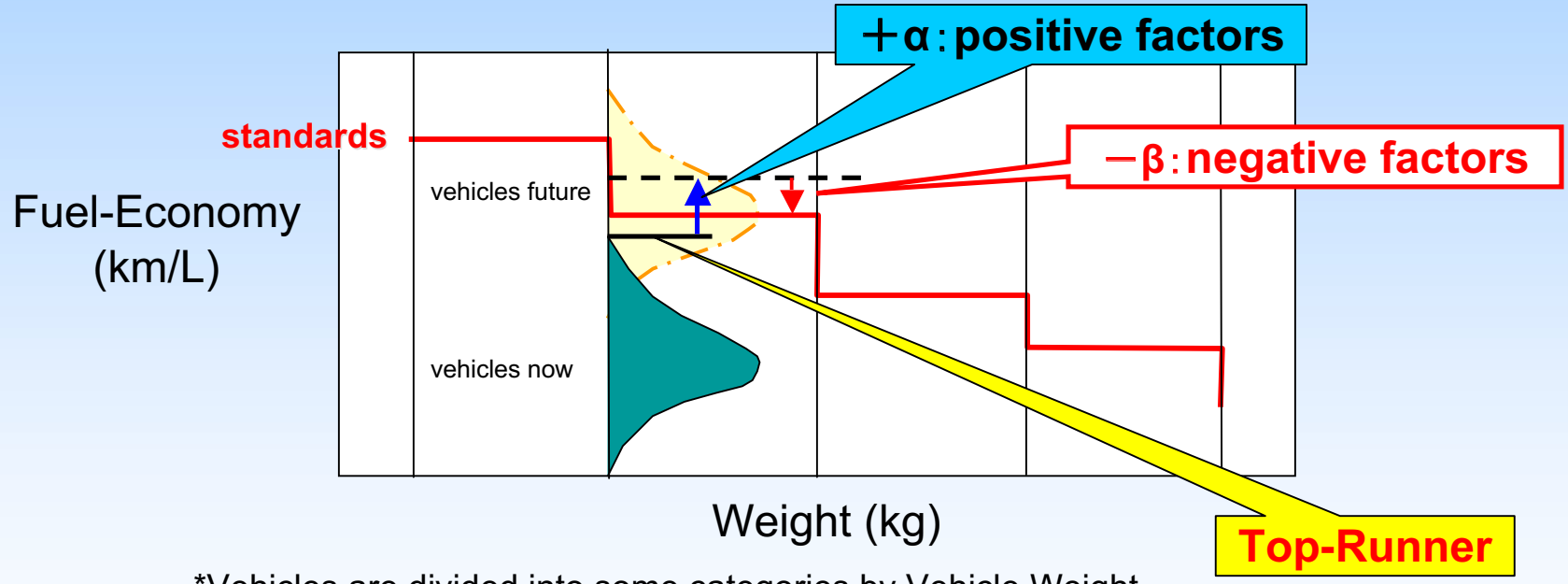
The world's first Fuel Economy Target Standard Values for Heavy-Duty Vehicles (diesel vehicles that weigh more than 3.5 ton), based on "Top-Runner Program", promulgated in 2006.

Manufacturers are required to improve Fuel Economy of Heavy-Duty Vehicles until target year 2015.

Top-Runner Standard for Fuel Economy

Target Standard Values based on Top-Runner Program

Based on the fuel economy of the most fuel efficient vehicle which is on sale (Energy Conservation Law)



*Vehicles are divided into some categories by Vehicle Weight which strongly influence their fuel economy

Positive Factors: Technological Improvement
Negative Factors: Exhaust Emission Regulations, etc.
(trade-off relation with fuel economy)

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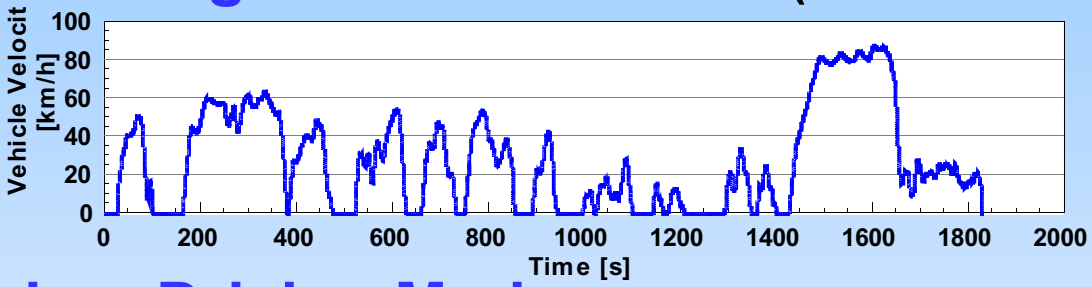
HDVs Fuel Efficiency Standard

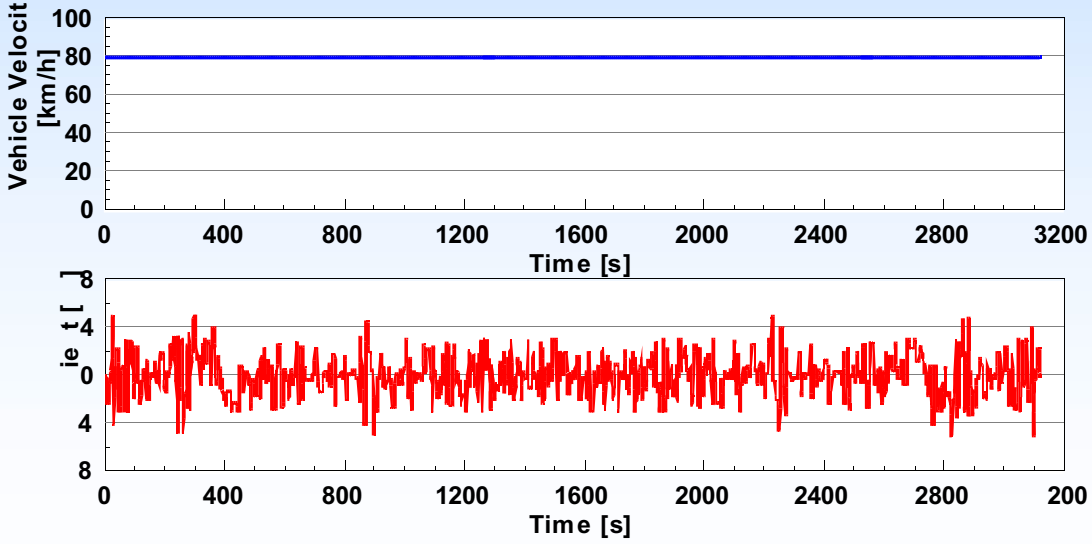
"Heavy Vehicle Mode"

- **Urban Driving Mode** = JE05 Mode (Emission Test Mode)



- **Interurban Driving Mode**

  = 80km/h Constant Speed Mode with Road Gradient



➡ **Evaluation of Fuel Efficiency by *Simulation Method***

Simulation Method Overview

Driving mode = { **Urban driving mode**, **Interurban driving mode** }

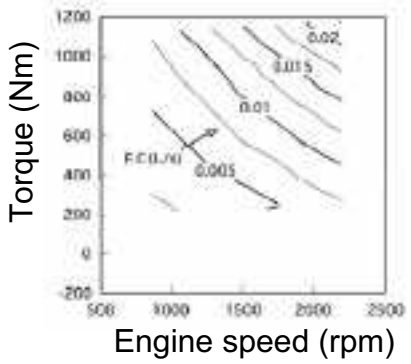
Conversion program
- Determine gear-shift positions.
- Calculate engine speed and torque.

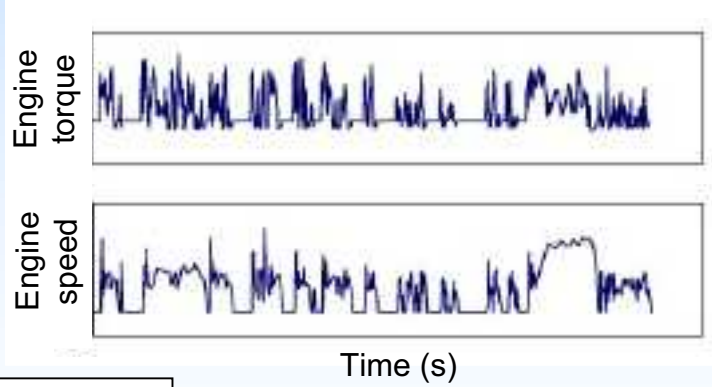
Vehicle specifications

Fuel efficiency map

Engine Operating Mode

Computing





Fuel consumption = $\sum_{i=start}^{end} F.C.(i)$

Fuel efficiency

*Before simulation, perform operation tests to create a fuel efficiency map

Phase of conversion

Speed vs. time

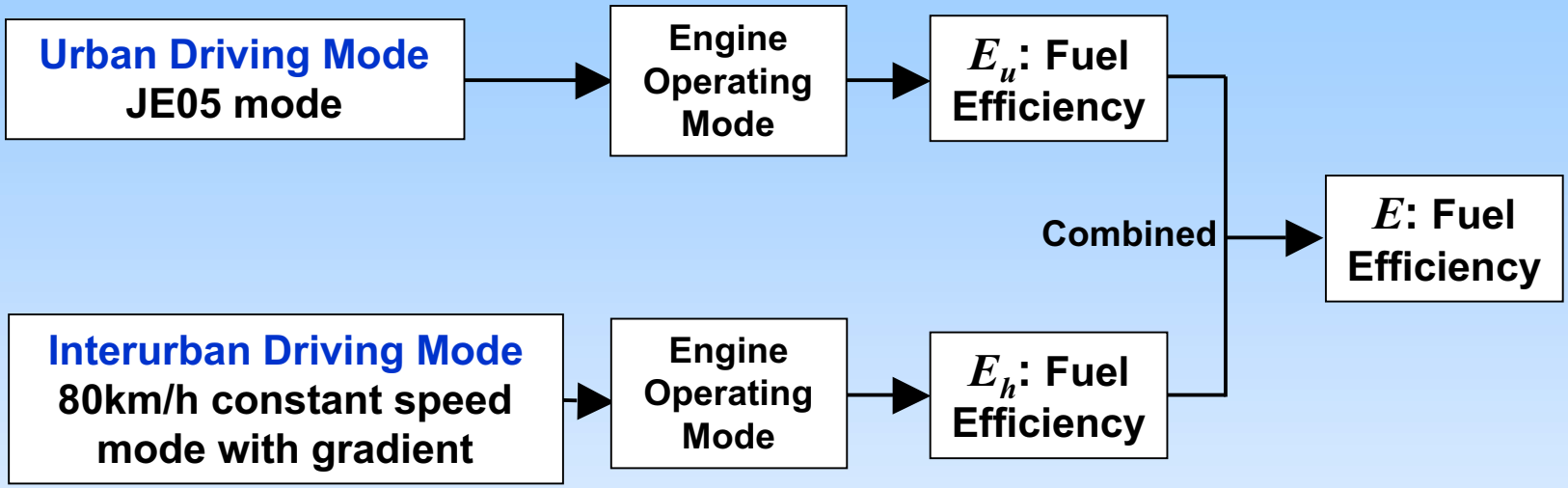
↓

Engine speed / torque vs. time

Phase of calculation of fuel efficiency

Source: Japan Automobile Research Institute: Survey Report on Evaluation Methods for Heavy Vehicles, March 2003

Simulation Method Flowchart and Equation



$$E = 1 / (\sum_u / E_u + \sum_h / E_h)$$

E: Heavy vehicle mode fuel efficiency (km/L)
E_u: Urban driving mode fuel efficiency (km/L)
E_h: Interurban driving mode fuel efficiency (km/L)
$\sum_u$: Proportion of urban driving mode
$\sum_h$: Proportion of interurban driving mode

Driving Distance Proportion by Driving Mode

$$E=1 / (\sum_u / E_u + \sum_h / E_h)$$

	Passenger vehicles (riding capacity : 11 persons or more)			Freight vehicles			
Vehicle Type	Ordinary bus		Route bus	Other than tractor		Tractor	
GVW	14 tons or less	Over 14 tons		20 tons or less	Over 20 tons	20 tons or less	Over 20 tons
Drive proportion							
Upper: $\sum_u$	0.9	0.65	1.0	0.9	0.7	0.8	0.9
Lower: $\sum_h$	0.1	0.35	0.0	0.1	0.3	0.2	0.1

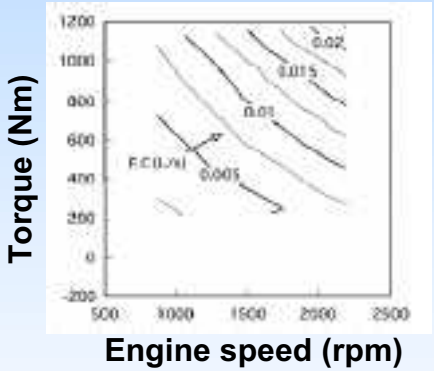
Characteristics of Simulation Method

“Simulation Method”

≠ Actual Engine Measurement Test by Driving Mode

- **Based on real vehicle and engine specifications**

Fuel consumption map



Engine related parameters

Drivetrain related parameters

- **The method is an extension of the emission test.**

→ Low cost and good test efficiency

→ Problems of reproducibility of driving resistance

Other Notes 1

1. AT and AMT Vehicles

a). AT vehicle (equipped with torque converter)

Urban drive mode: E_u x 0.91

Interurban drive mode: E_h x 0.96

b). AMT (automated manual transmission) vehicle

Same as the ordinary MT vehicle

2. Vehicles equipped with a post treatment device with forced regeneration control

Vehicles equipped with a post treatment device such as continuous regenerative DPF (diesel particle filter) have a different engine control that cannot be covered by the normal operation fuel efficiency map.

⇨ Calculate the ratio in fuel efficiency between vehicles with and without the forced regeneration control

Other Notes 2

3. Accuracy of the Simulation Method

- A fuel efficiency estimated by using “fuel efficiency map” based on the simulation method

  vs.

- A fuel efficiency obtained by the vehicle-based actual measurement

⇒ The error by the simulation to the actual measurement

= Limited to about 0.4% irrespective of the types of HDVs

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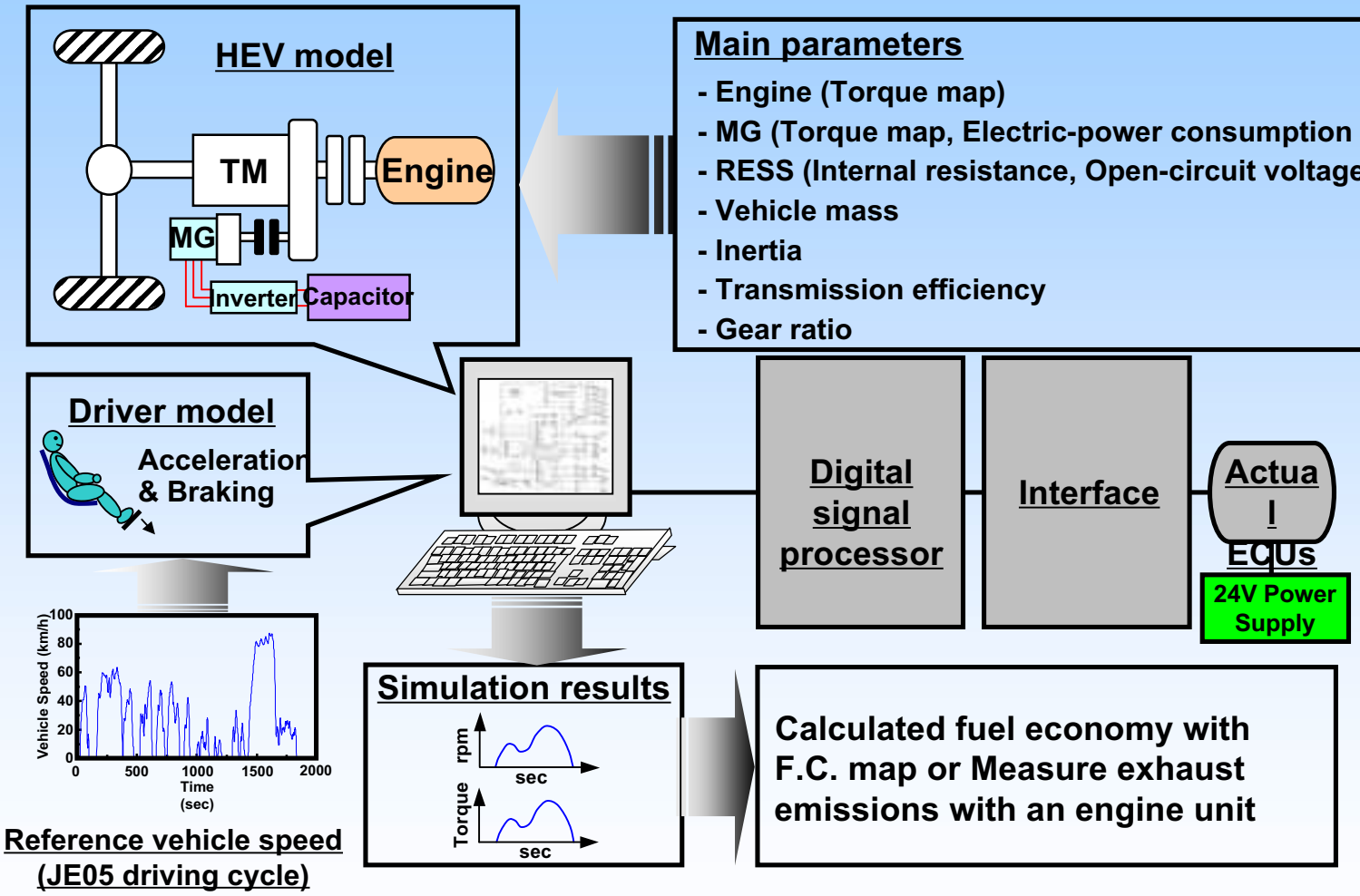
Introduction Background of HILS Test Method

- **Fuel Efficiency Test**
  - ⇒ simple method: Simulation Method
- **Emission Test**
  - ⇒ dynamo test with only engine: without electric system
- **System Bench Method for Hybrid Vehicles**
  - The E/D system composed is complex
  - 4-wheel drive vehicles, in-wheel motor : need of multiple E/D

- **Development of Hardware-In-the-Loop Simulator (HILS) Test Method**

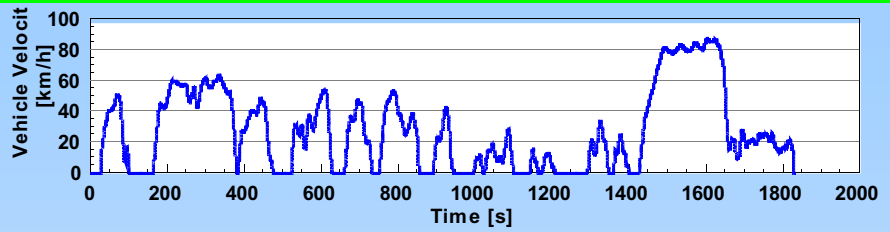
HILS System


HEV model
TM
Engine
MG
Inverter
Capacitor
Main parameters
- Engine (Torque map)
- MG (Torque map, Electric-power consumption map)
- RESS (Internal resistance, Open-circuit voltage)
- Vehicle mass
- Inertia
- Transmission efficiency
- Gear ratio
Driver model
Acceleration & Braking
Digital signal processor
Interface
Actual ECUs
24V Power Supply
Vehicle Speed (km/h)
Time (sec)
Reference vehicle speed (JE05 driving cycle)
Simulation results
rpm
Torque
sec
Calculated fuel economy with F.C. map or Measure exhaust emissions with an engine unit

Test Procedure Outline for Hybrid HDVs

1st Step

Urban Driving Mode
Interurban Driving Mode



Simulated driving by HILS Program to determine Engine Torque & Engine Speed, to check HEV model

Input

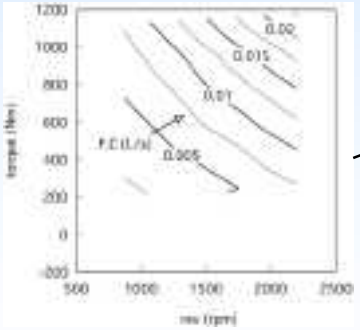
Vehicle Specification
Vehicle weight, Driving Resistance, Full load engine torque, Motor characteristics, Battery characteristics, etc.

Connect

Hybrid ECU

2nd Step

Engine Operating Mode



Input

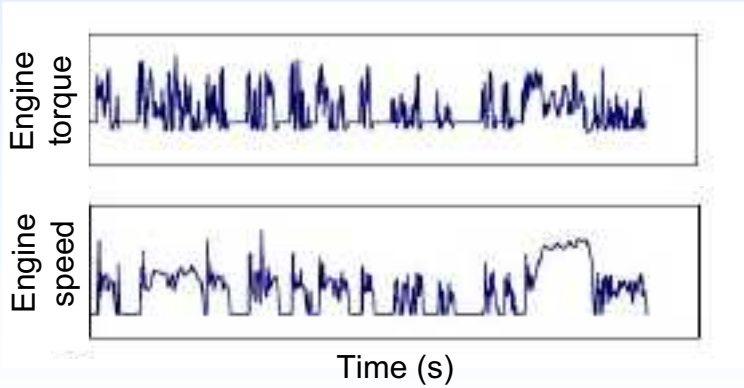
Fuel consumption

$$= \sum_{i=start}^{end} F.C.(i)$$

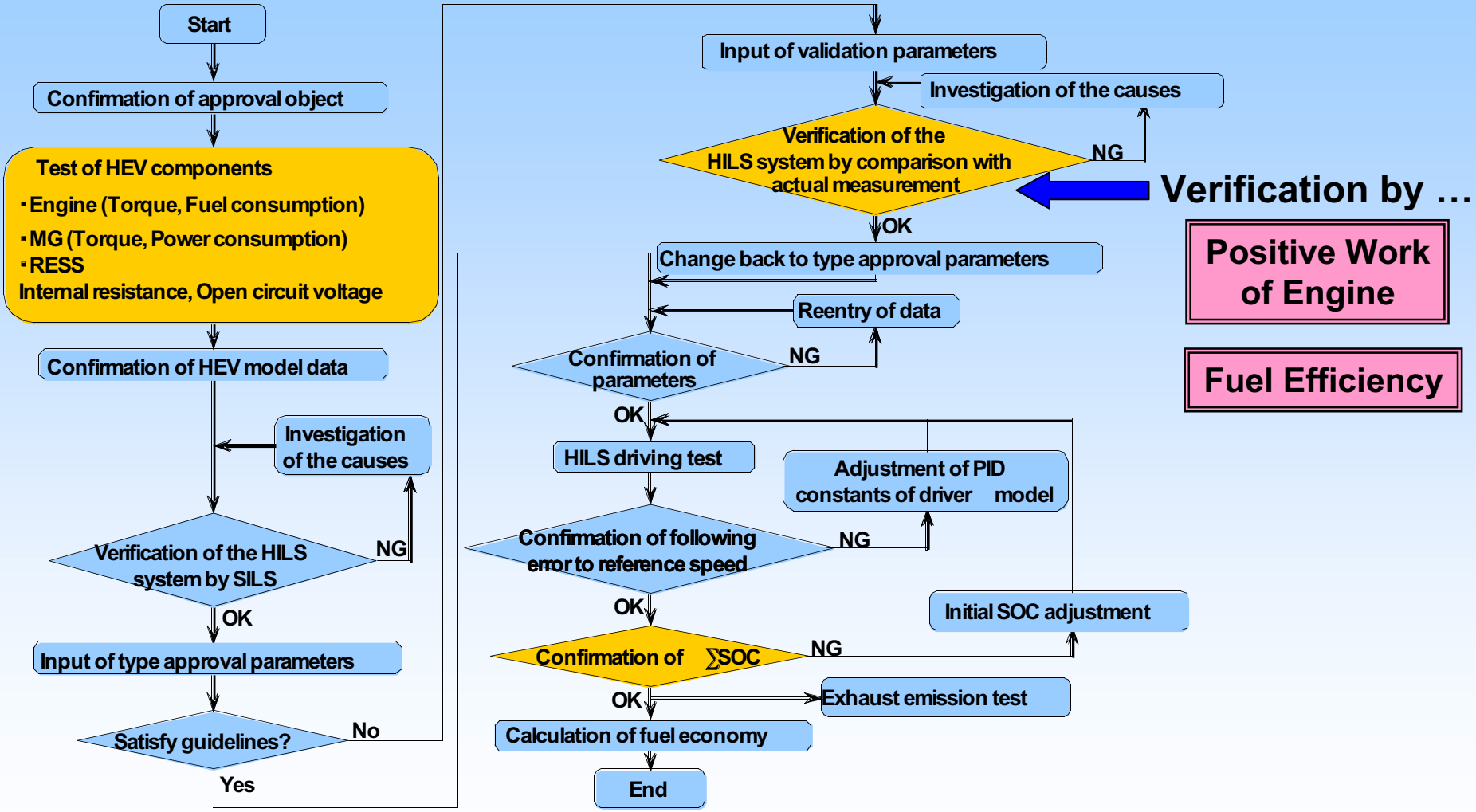
Fuel efficiency

***Before simulation, perform operation tests to create a fuel efficiency map**

Fuel Economy Test: Simulation Method



Flowchart of HILS Test Method



Fuel consumption & exhaust emission test method for HD-HEVs using HILS system, National Car Environments Notice No. 281, March 2007

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Summary

1. Fuel Economy Target Standard Values for Heavy- Duty Vehicles were set in Japan for the first time in the world.

2. Simulation Method is an extension of the emission test, so that the cost of the fuel efficiency test is low and its test efficiency is good.

3. The New Fuel Economy Test Method for Hybrid HDVs that combined HILS and Simulation Method has been developed.

Thank You for Your Attention

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