Introduction of practical uses of Plant Model in Model Based Development

AISIN AW CO.,LTD
ADVANCED ENGINEERING GROUP
ELECTRONIC ENGINEERING DEPARTMENT
SENIOR SPECIALIST
TAKAYUKI KUBO

Agenda

1. Introduction
2. Status of activities for Model Based Development
    1. H I L S *development*
    2. H I L S *engineer curriculum*
    3. MATLAB basic text
3. Control system development
    1. The first try to Control logic development
    2. NEW Control logic development
4. Plant model development
5. Examples of application
6. Expectations for SimDriveline
7. Activities for Automatic Code Generation (ACG)
8. Closing

1.Intoducion : Company summary

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Company Name AISIN AWCO.,LTD.

Establishment May 15 , 1969

Consolidated sales 958,300,000,000 Yen

≒US$ 9,583 million

(Unconsolidated sales 876,400,000,000 Yen)(FY2007)

≒ US$ 8,764 million

Number of employees 16,750 (31-Mar-2008)

(US 1dollars = 100Yen)

Main three products of AISIN AW

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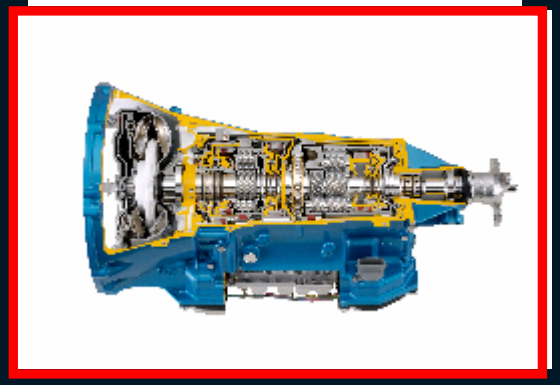
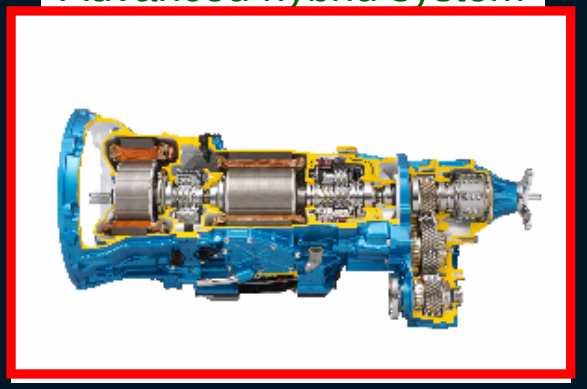
Automatic Transmission (AT)

Comfort and environment-friendly driving

High-spec multi-step AT



Advanced hybrid system



Comfort and safety driving

High-spec car- navigation system

Offices

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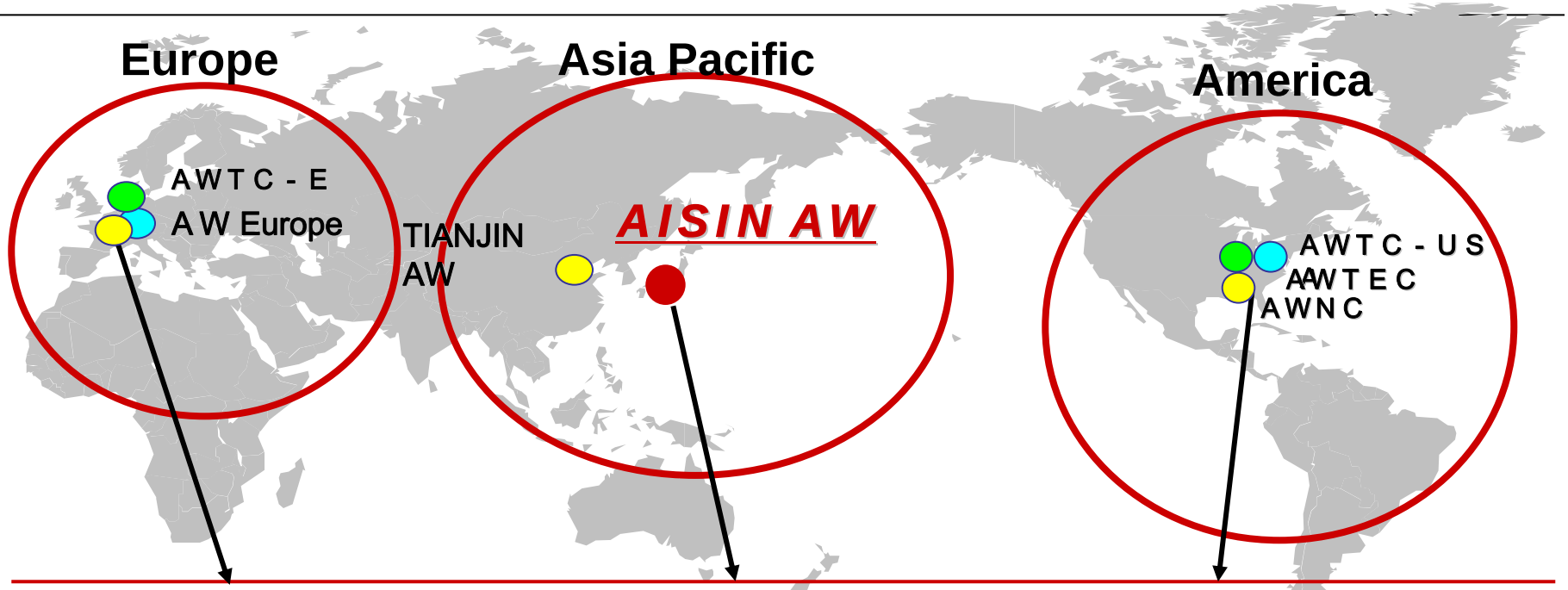
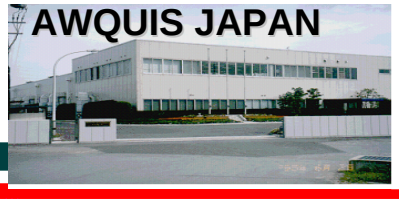


Engineering

Production

Service



Current Business Status

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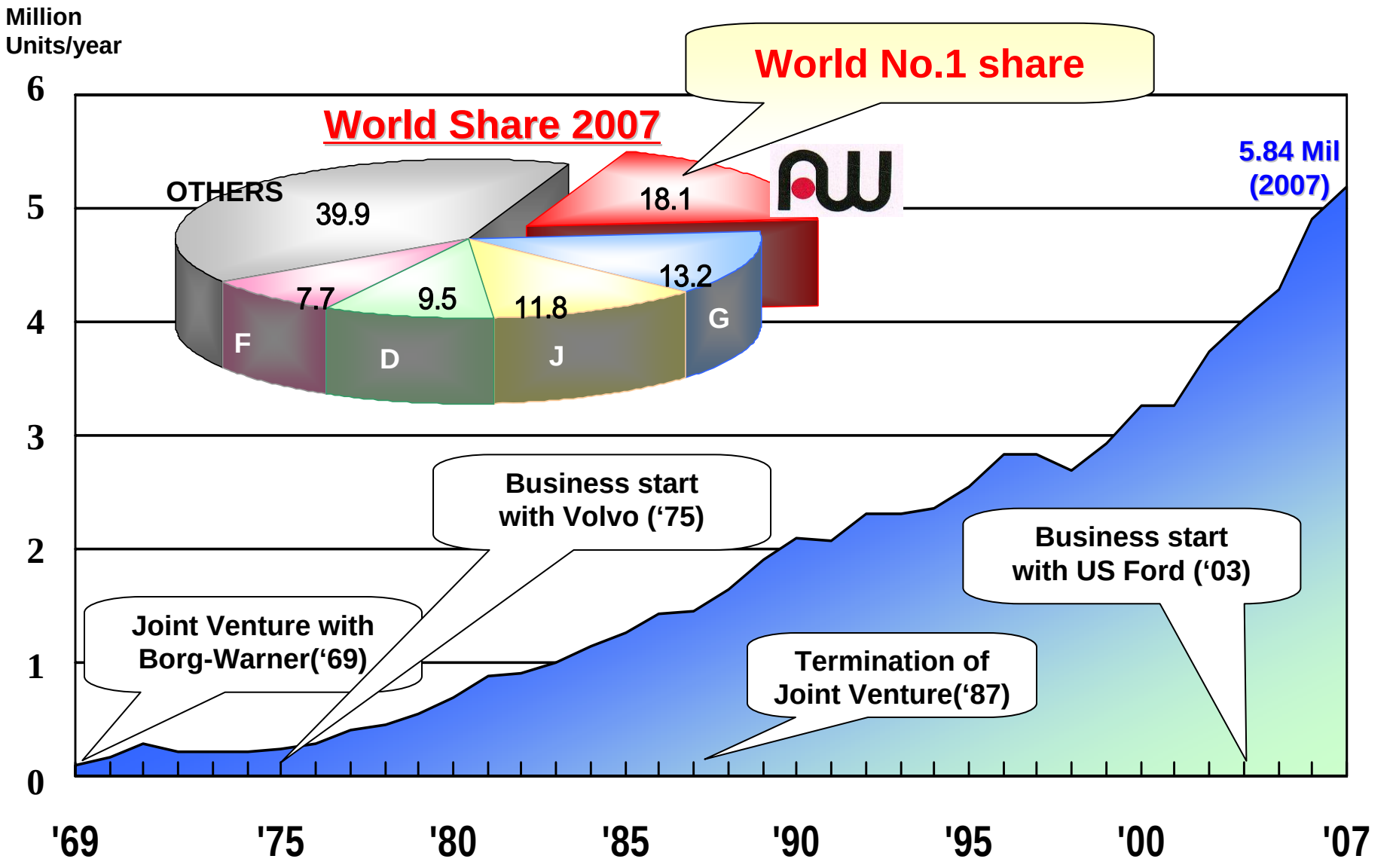

Introduction of latest new products

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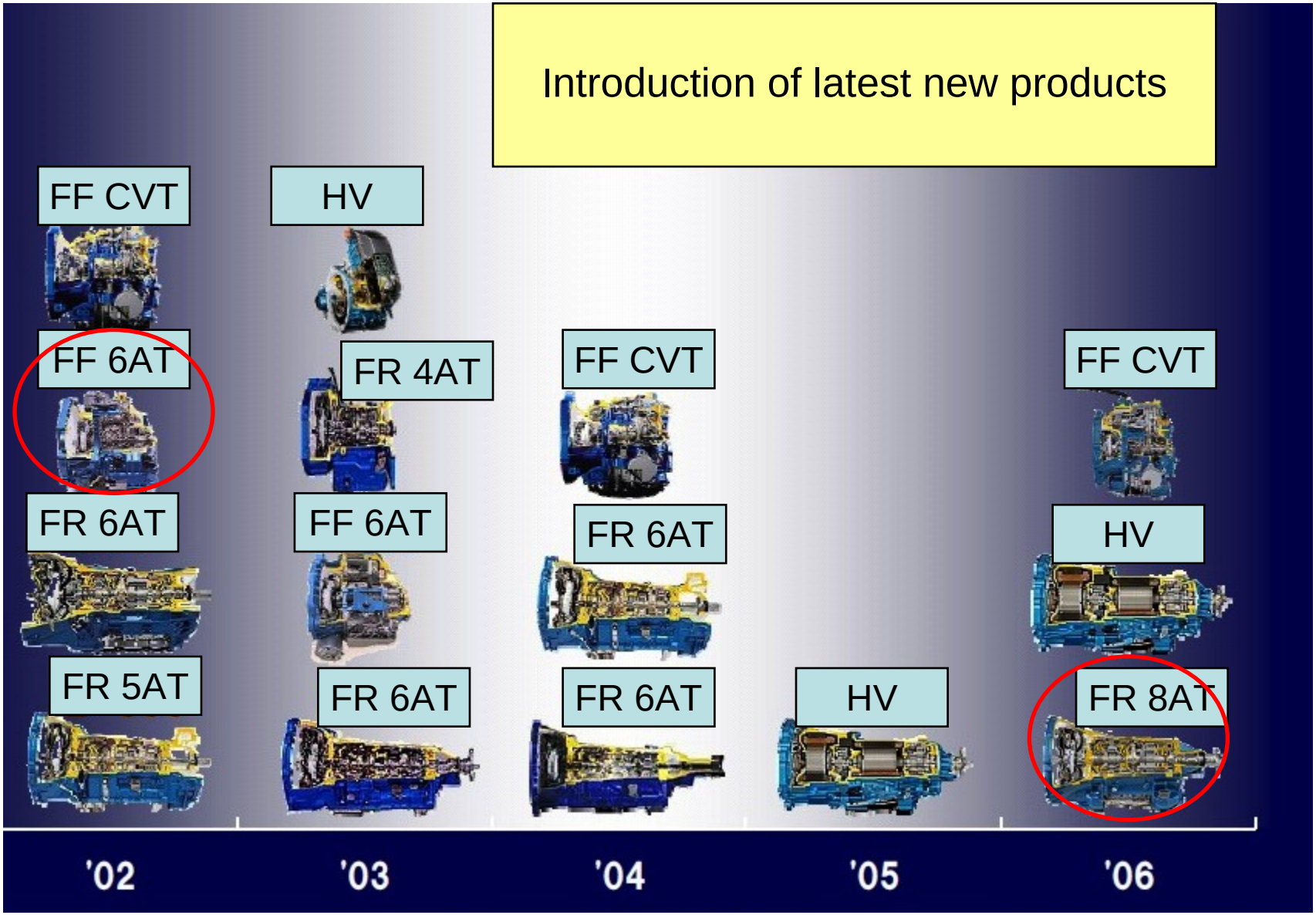
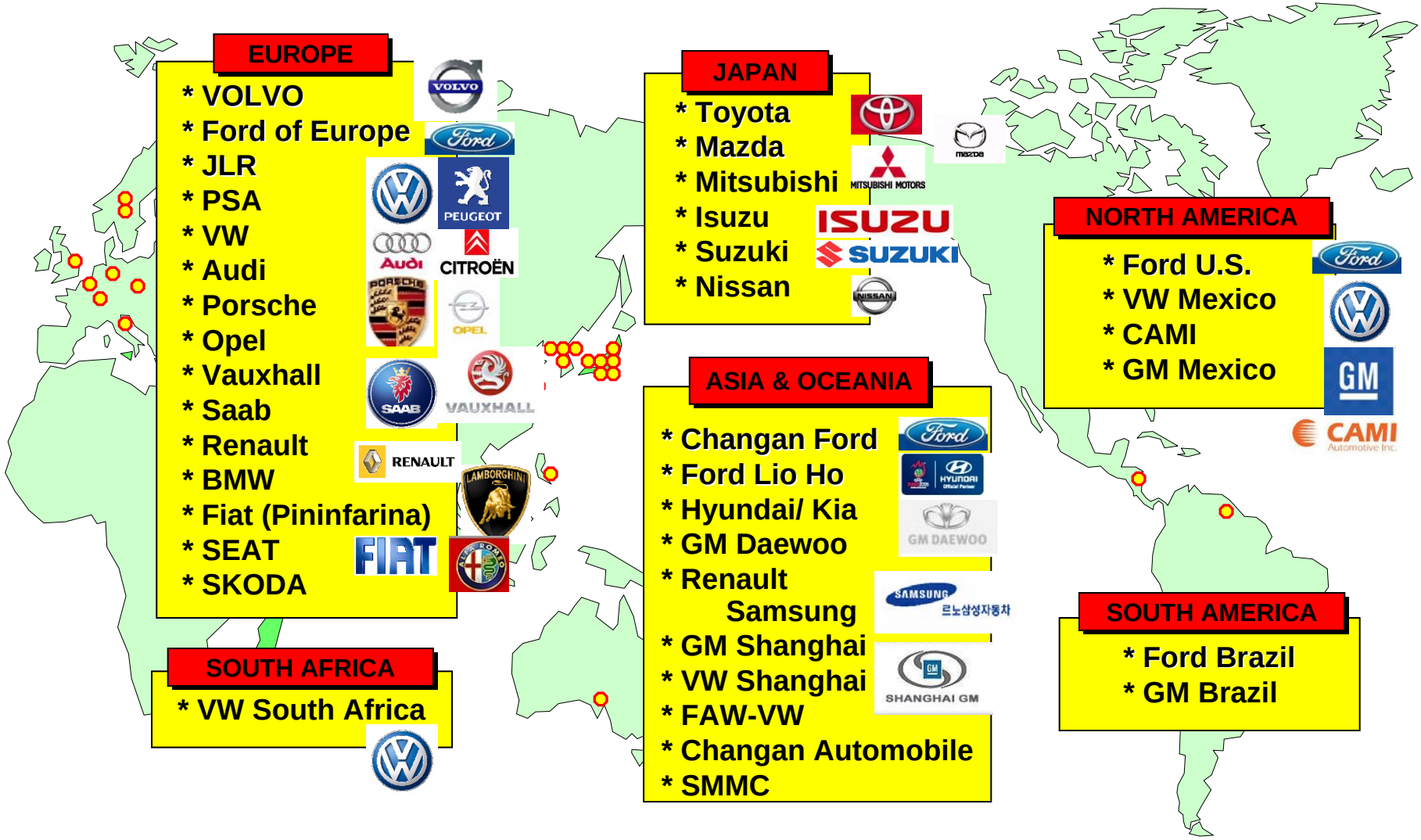


- **38** CUSTOMERS AROUND THE WORLD - 3 June 2008



EUROPE
* VOLVO
* Ford of Europe
* JLR
* PSA
* VW
* Audi
* Porsche
* Opel
* Vauxhall
* Saab
* Renault
* BMW
* Fiat (Pininfarina)
* SEAT
* SKODA

JAPAN
* Toyota
* Mazda
* Mitsubishi
* Isuzu
* Suzuki
* Nissan

NORTH AMERICA
* Ford U.S.
* VW Mexico
* CAMI
* GM Mexico

ASIA & OCEANIA
* Changan Ford
* Ford Lio Ho
* Hyundai/ Kia
* GM Daewoo
* Renault Samsung
* GM Shanghai
* VW Shanghai
* FAW-VW
* Changan Automobile
* SMMC

SOUTH AMERICA
* Ford Brazil
* GM Brazil

SOUTH AFRICA
* VW South Africa

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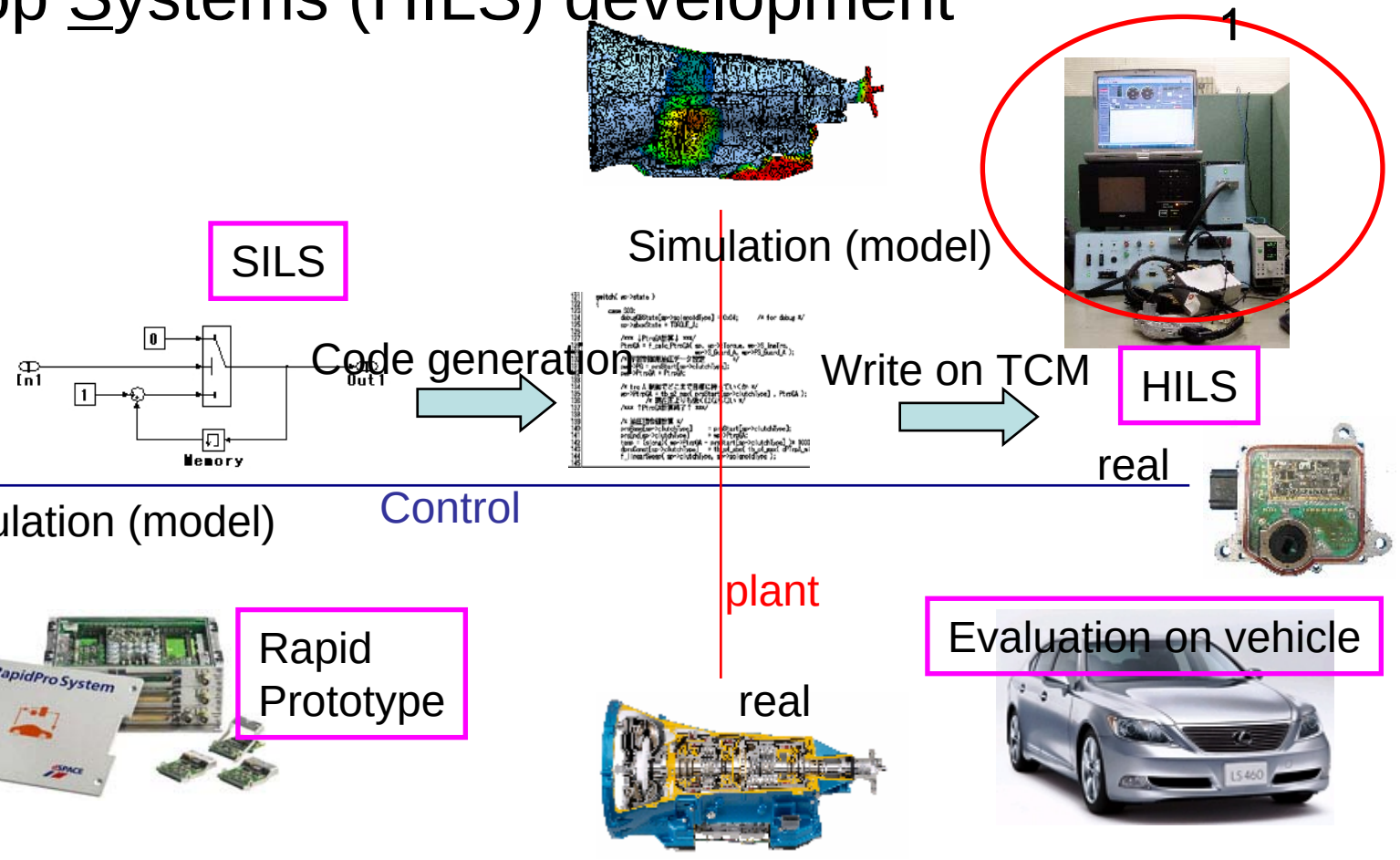
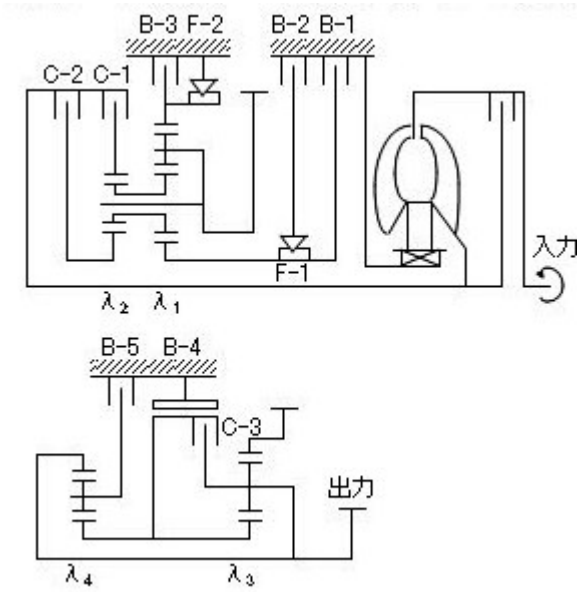
•Reason of why activities for Model Based Development were started from Hardware In the Loop Systems (HILS) development

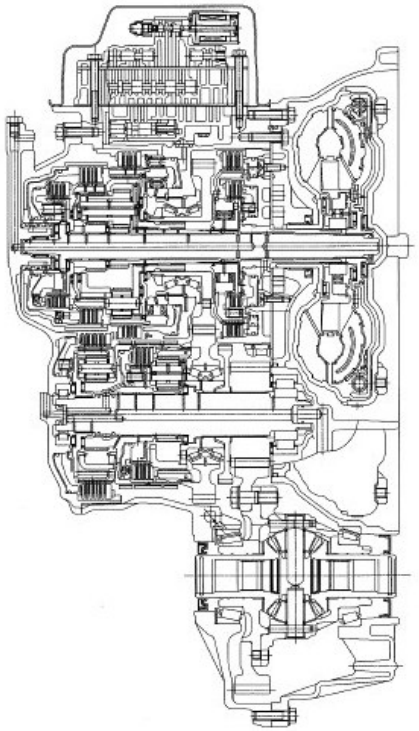


Background of H I L S development

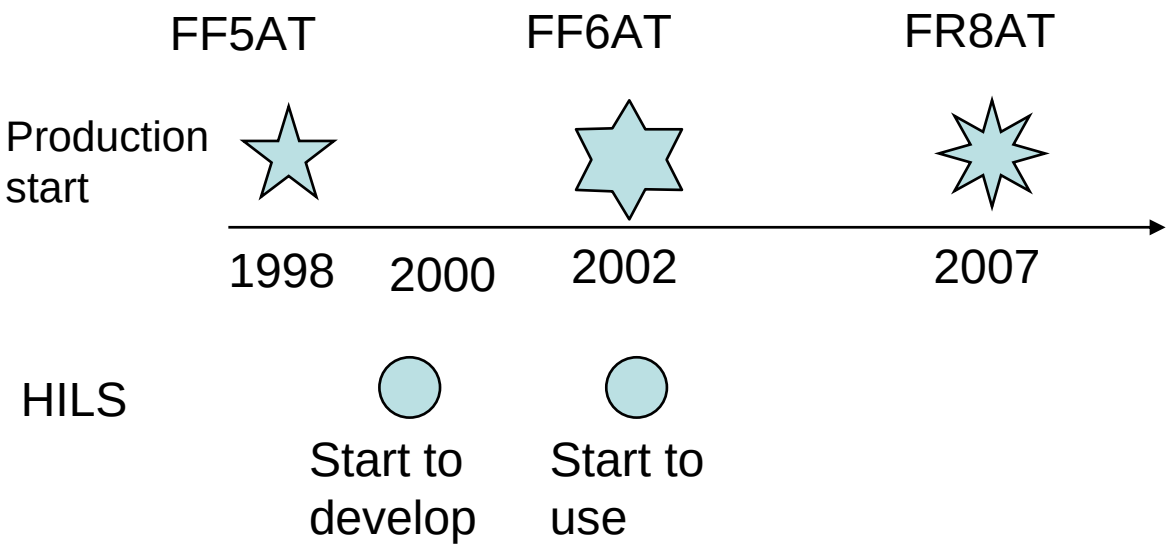
- In 1998, we succeeded in production of five-speed A/T.
- At this time, amount of control specification increased to ten times of four-speed A/T's one.
- And same time, software size and necessary man-hour for software testing increased more.

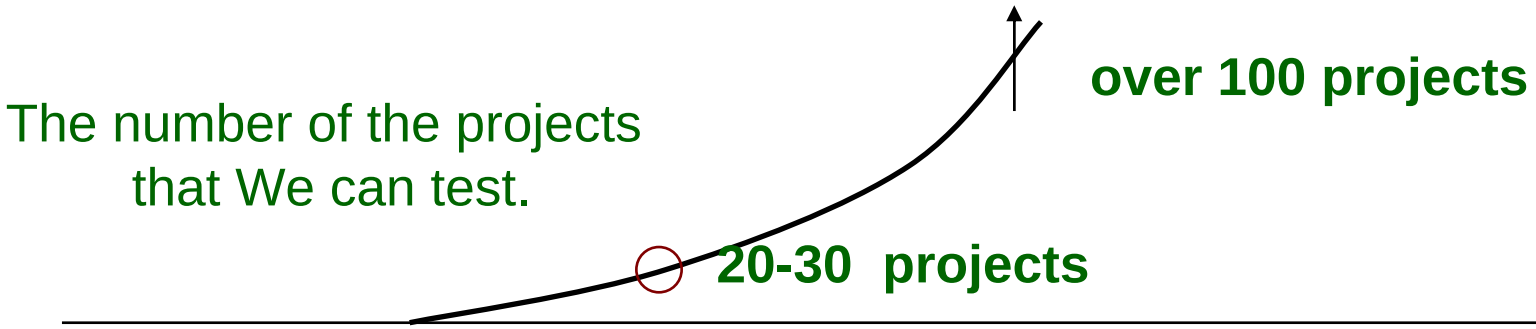
5speed A/T





- Around 2000, HILS development was started.
- In 2002, we started the use of the HILS device.



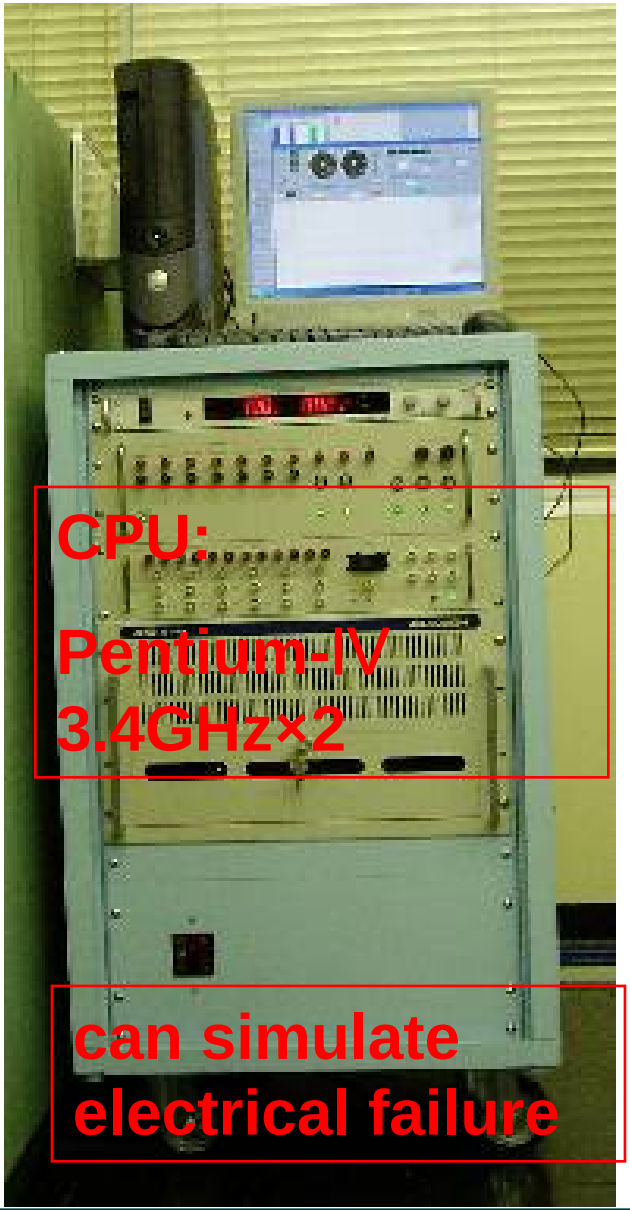


- Two types of HILS were developed.
  - Multi-node HILS
  - Small-scale HILS

CPU:
Pentium-M2.1GHz

purchasing cost is half

can't simulate electrical failure



CPU:
Pentium-IV 3.4GHz×2

can simulate electrical failure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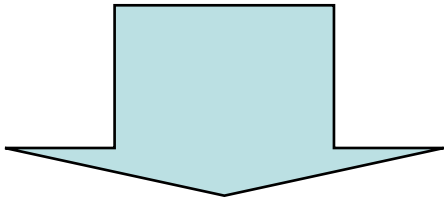
HILS system
HILS models

- Necessary man-hour for software testing was reduced
- Other effects
  - Skill definition for education based on **E**mbedded **T**echnology **S**kill **S**tandards - **J**apan **M**atlab **A**utomotive **A**dvisory **B**oard (**ETSS-JMAAB**)
    - Basic curriculum for HILS engineer was established
    - Beginner's text of MATLAB/Simulink was completed
  - MBD was recognized in our company
    - Effect of HILS is recognized in our company too.



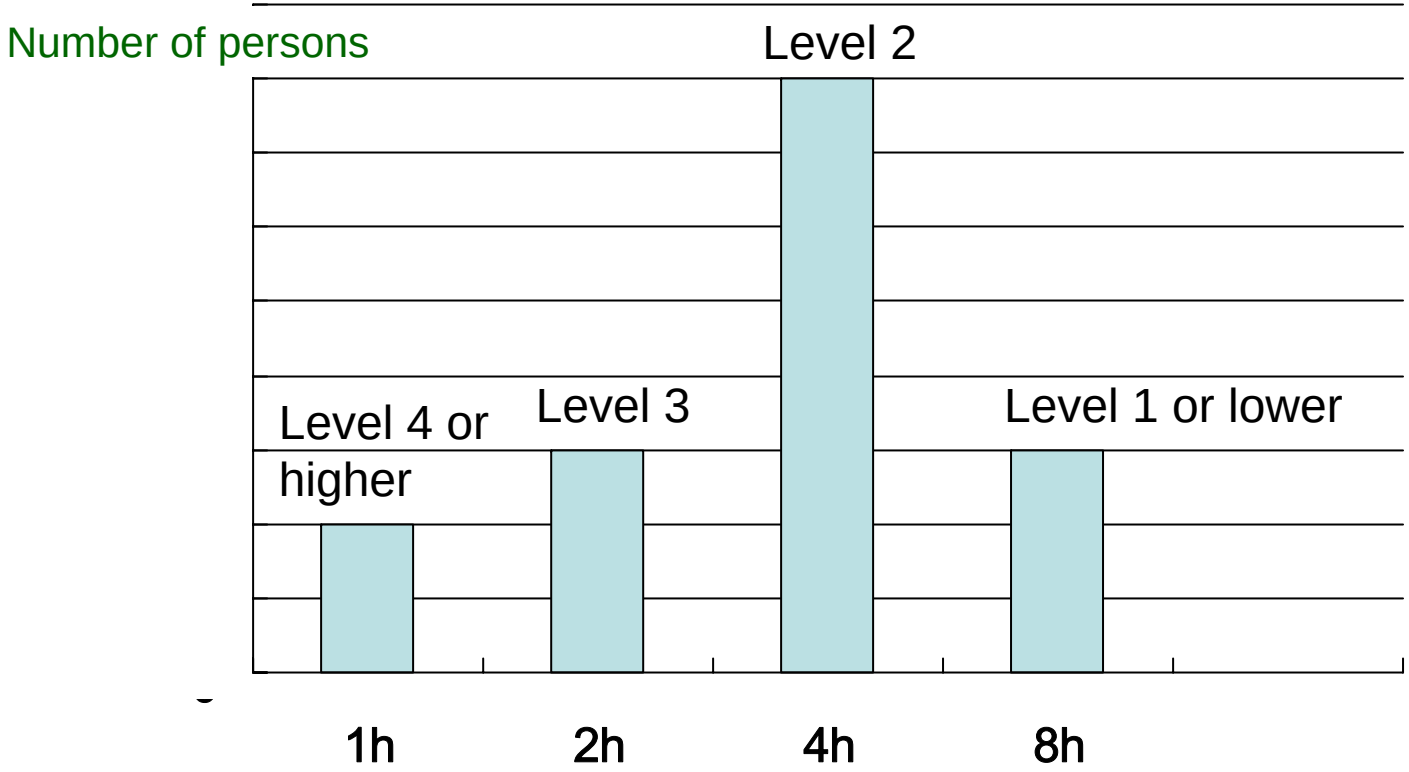
In 2006, application of MBD for control logic development was started.

Based on ETSS-JMAAB, basic curriculum was established.

1. Distinguish engineers by level
2. Analyze engineers
3. Specify necessary skills for each level
4. Establish curriculum

Distinguish engineers by level

- Comparison of hours for same work



Distinguish engineers by seven degrees of levels

2.2 HILS engineer curriculum

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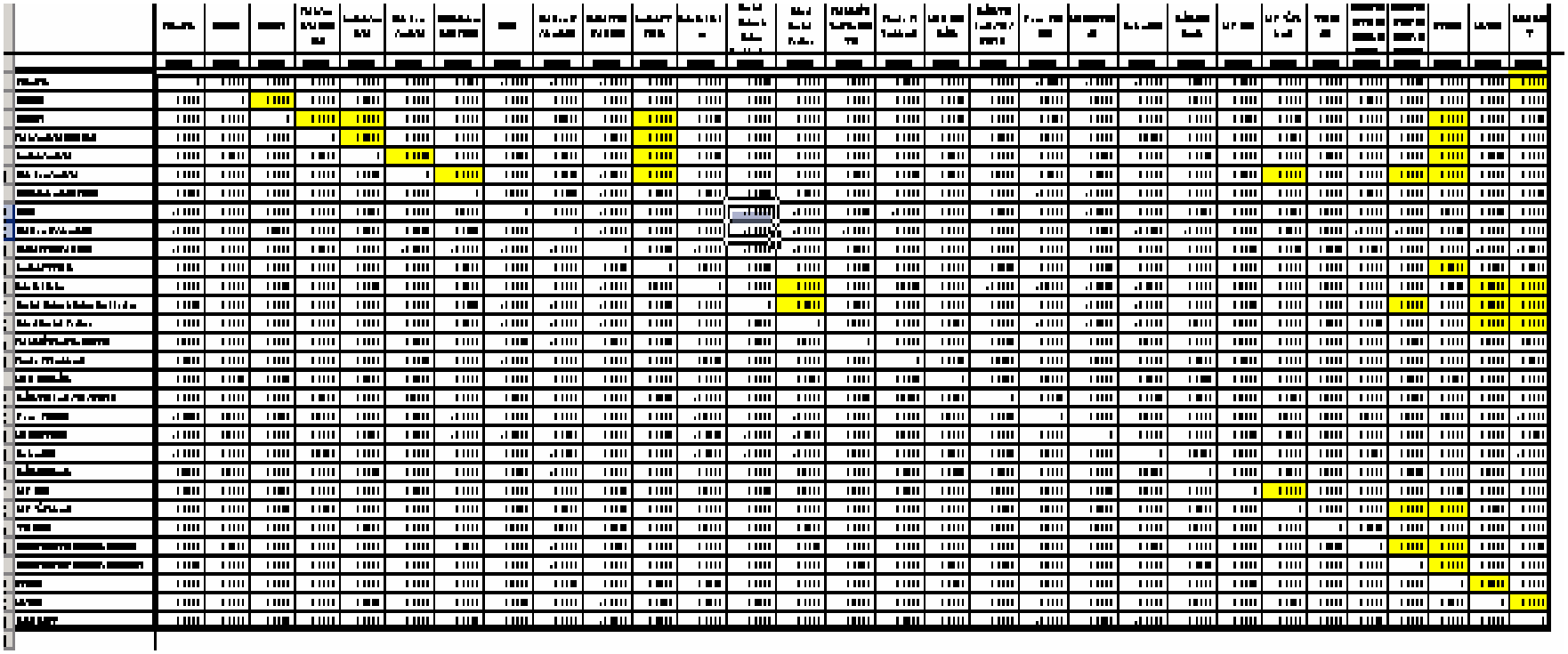
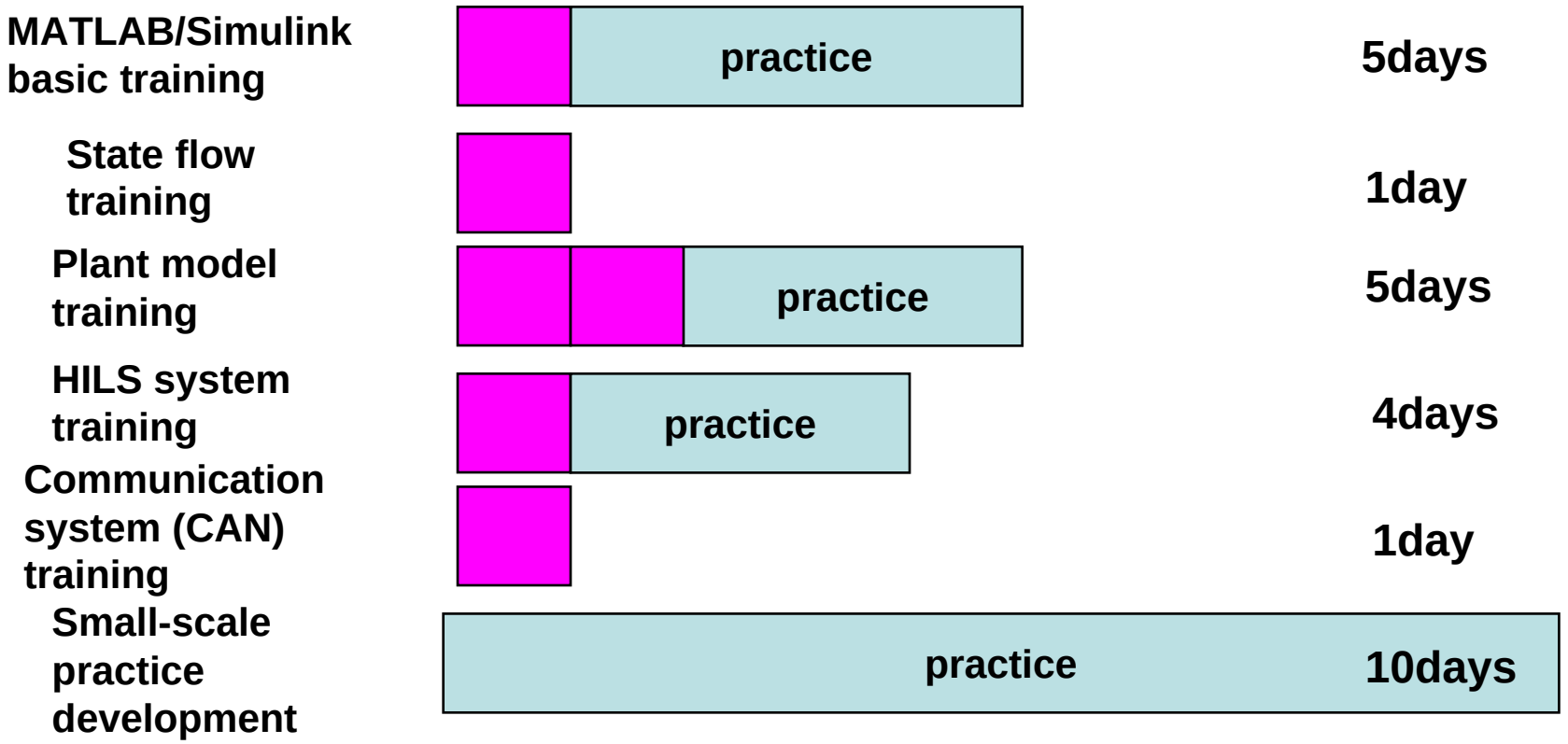
About items on basic curriculum

- In order to find the correlation between level and skill, multivariate-analysis was used.



2.2 HILS engineer curriculum

Example of basic educations for HILS engineer (guidance for Level 1)



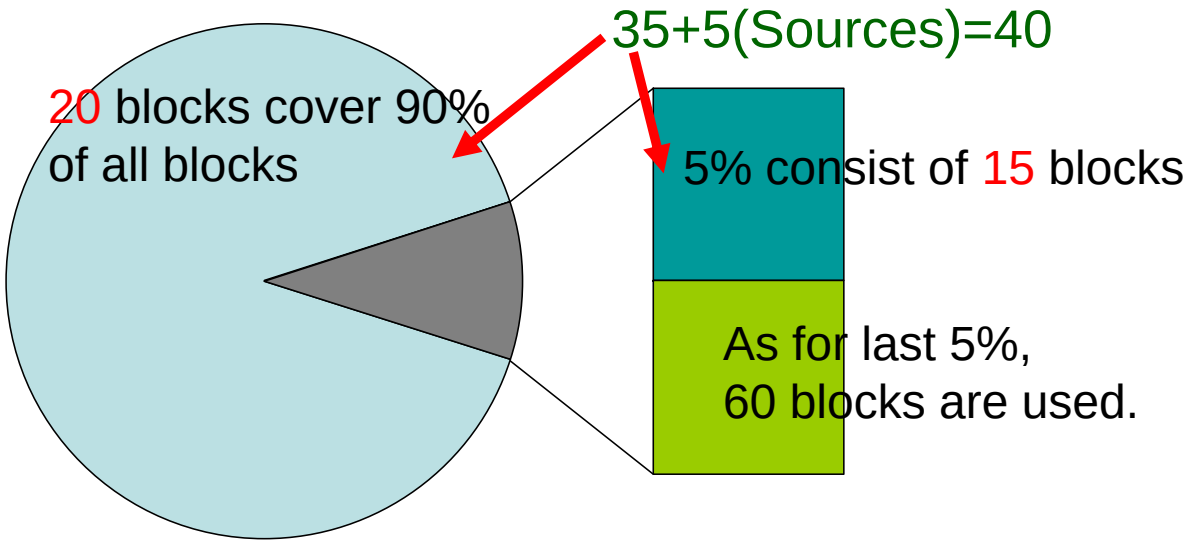
Before curriculum was established, some engineer could not reach to Level 1 in three month.
However, after well-organized curriculum was established, novice could reach to Level 1 in a month.

2.3 MATLAB basic text

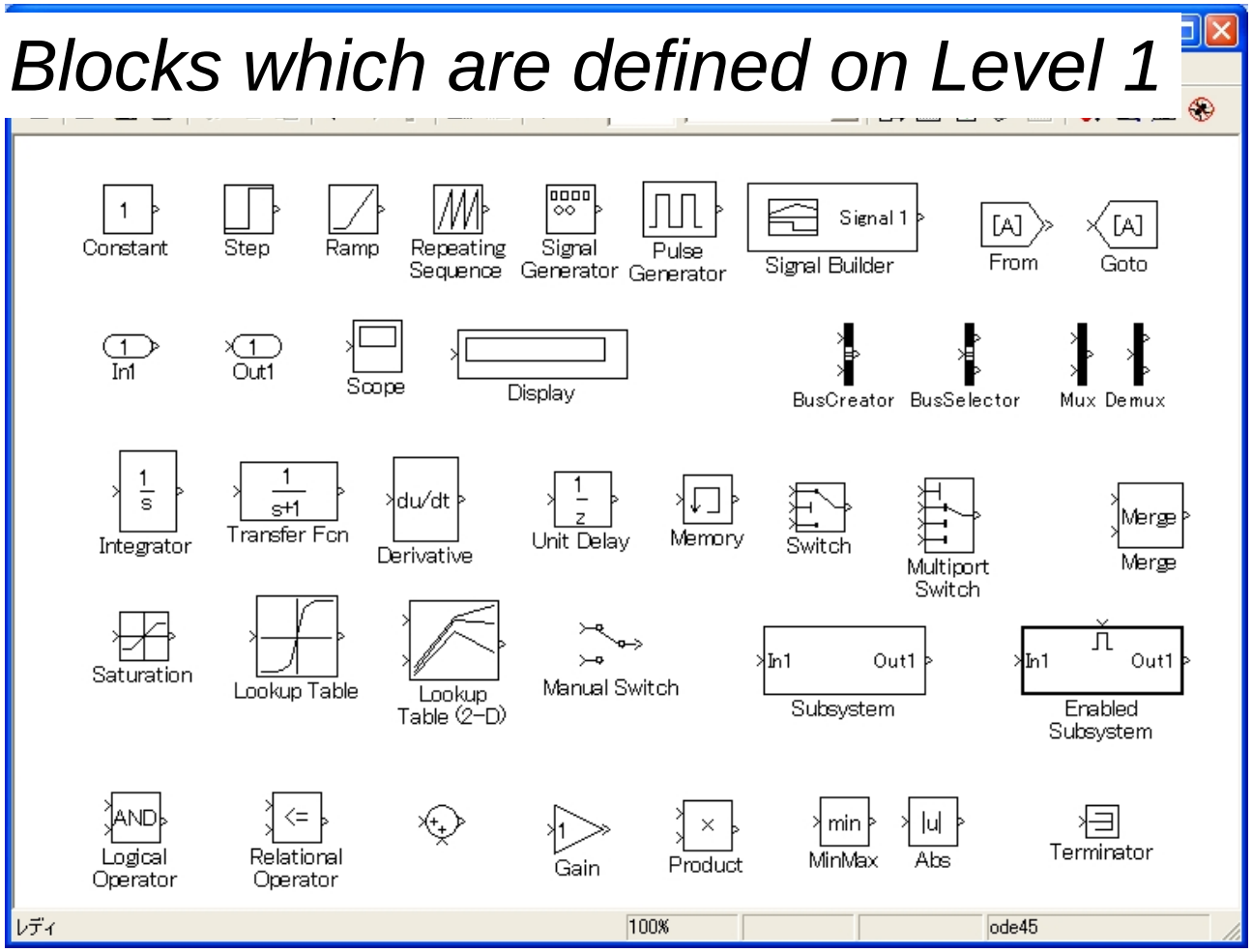
How MATLAB basic text was created.

Example : 100 + α kinds of blocks which are used in HILS models were investigated.

Level 1 : Limited to 40 kinds of blocks. However they covered 95% of whole HILS model.



Blocks which are defined on Level 1



In case of control specification model :

90% is covered by Level 1 blocks.

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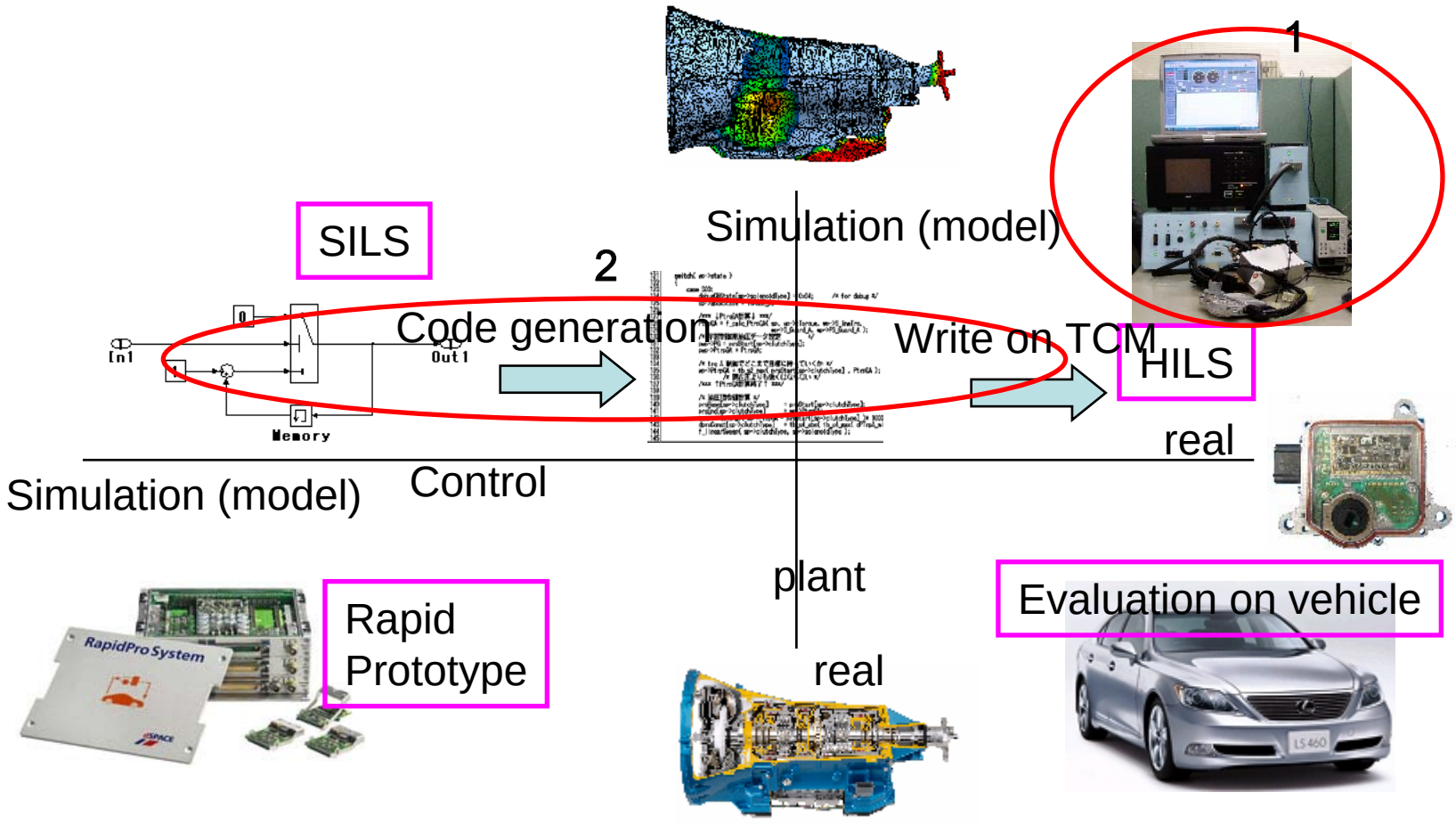

1
SILS
Simulation (model)
2
Code generation
Write on TCM
HILS
real
Simulation (model)
Control
plant
Rapid
Prototype
real
Evaluation on vehicle

- Activities for control logic development and Automatic Code Generation was started from 2002.
- In this development, C source code was automatically generated.

	Size	Number of blocks
Model	675Kbyte	1056
Generated C-code	162k	(7 files)

Control logic specification development
Automatic Code Generation

Know-how

HILS development

Know-how

New group for Control logic specification developing was established.

Area to which MBD is adopted and its schedule are decided

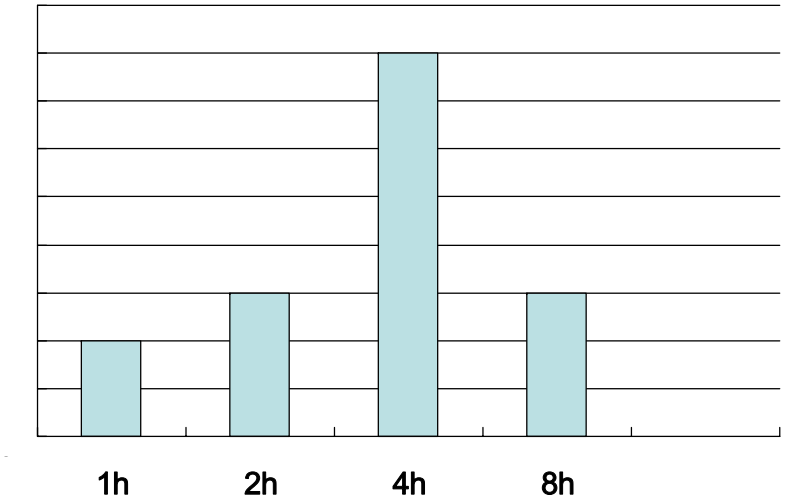
- Conventional method and MBD are :
  - Not same levels
  - Not same processes

Therefore, strict comparison is impossible.

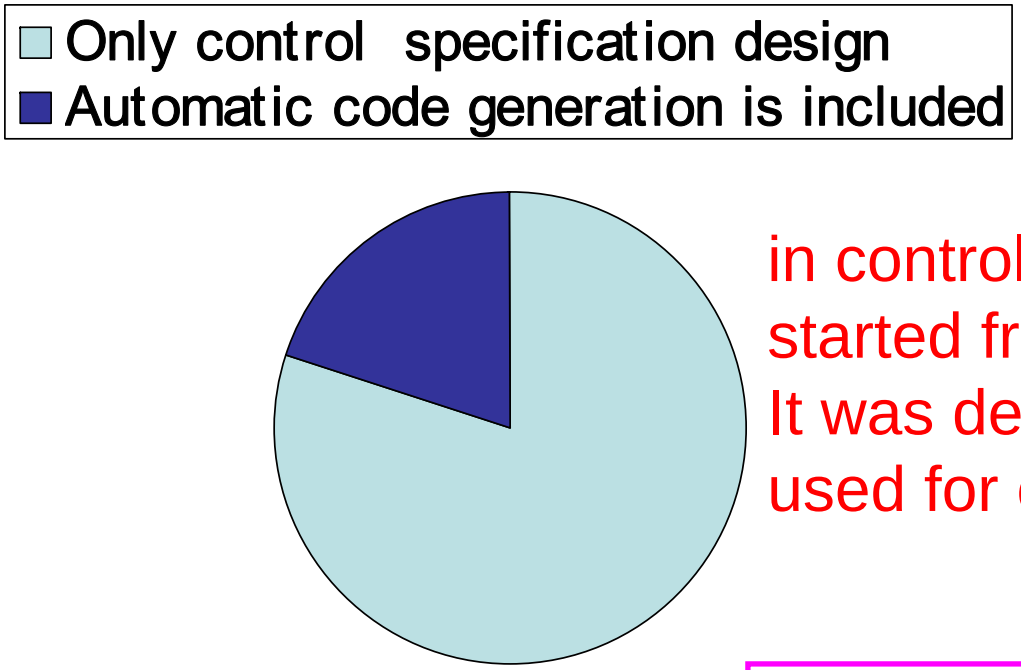
Experimental opinions and feelings are regarded as important

We decided to attach a great deal of importance on the opinions of MBD engineers through their experience.

Same work can cause ten times of man-hour difference in engineer's level



Adopting area is decided based on MBD engineer's opinions.

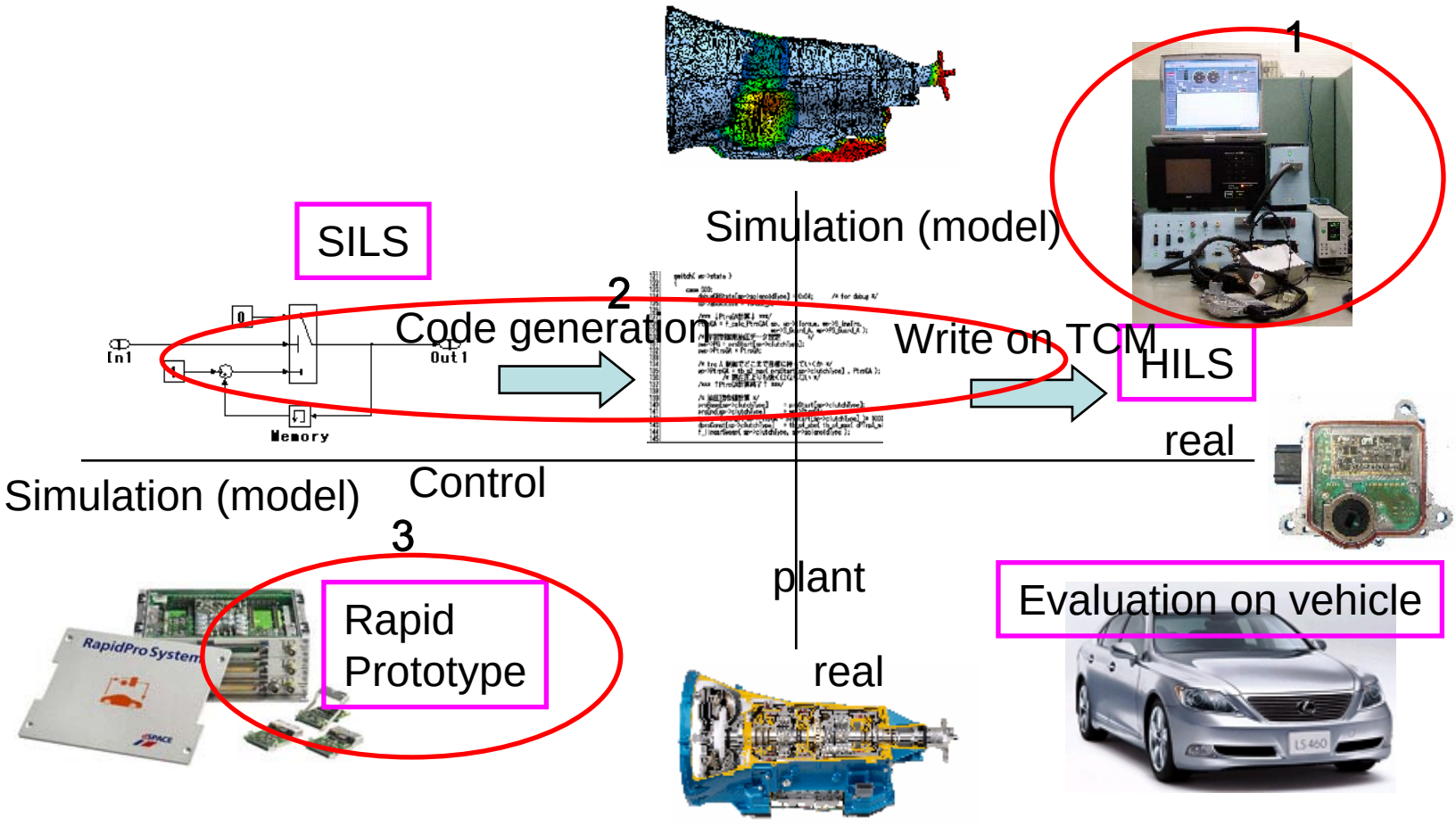


in control logic developing team started from 2006.
It was decided MBD was mainly used for only control logic design.

The Rapid Prototype is utilized for control logic development.

As for Automatic Code Generation, feasibility study was continued.

3.2 NEW Control logic development



System which has been tried since 2006

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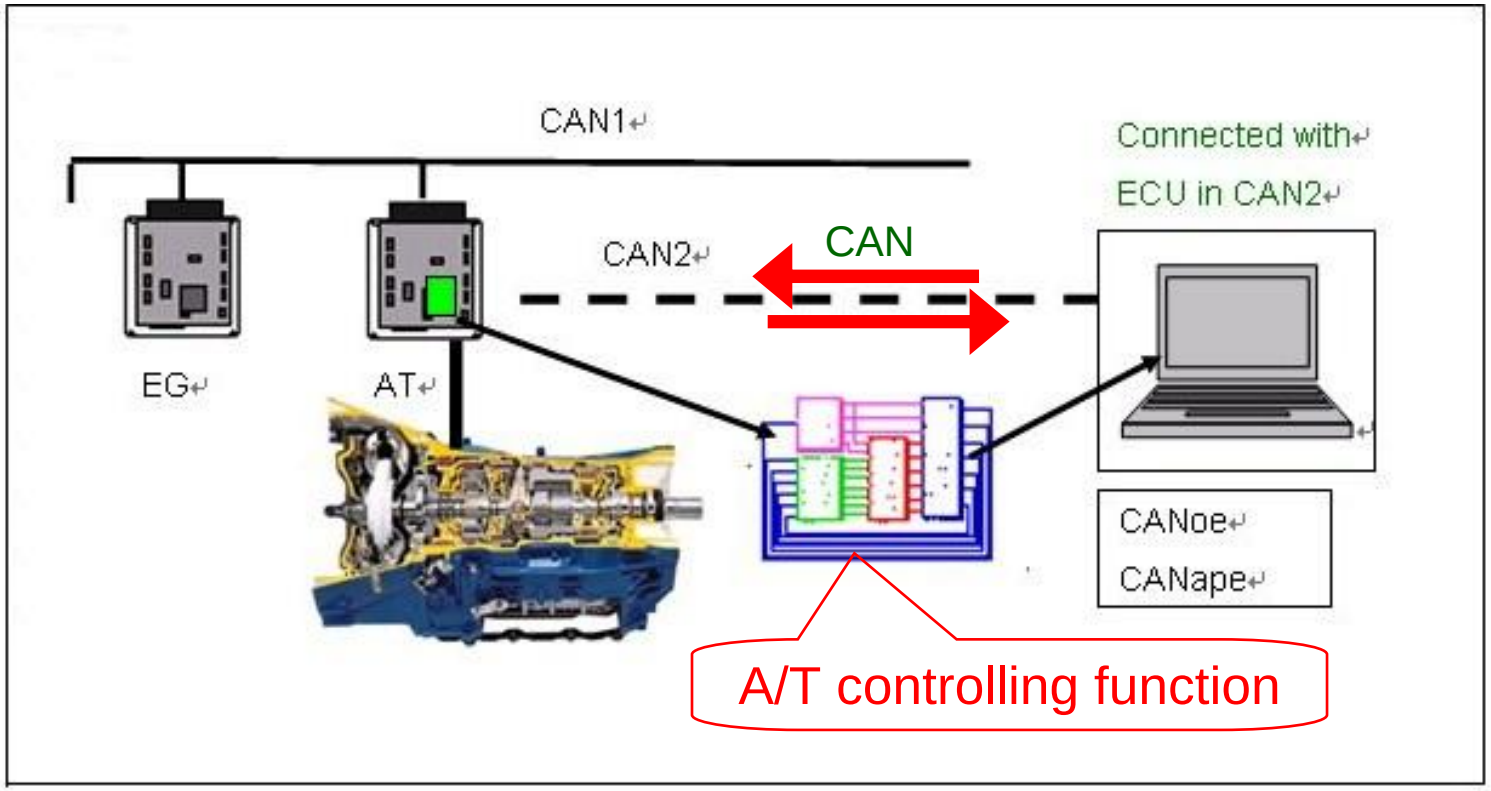
Bypass Rapid Prototyping method which uses CANoe/CANape



A part of control logic is described by using Simulink/Stateflow.
Corresponding part of production part is replaced by it.
Each signal is sent to and received from ECU on CAN

Size of controller and plant model

Case 1

	Size	Number of blocks
Controller	387Kb	634
Plant model	146Kb	947

Case 2

	Size	Number of blocks
Controller	500Kb	433
Plant model	440Kb	589

Numbers of blocks are investigated by using sldiagnostics('sys','CountBlocks').

Size of controller (no Plant model)

Case 3

	Size	Number of blocks
Controller	392Kb	390
Plant model	-	

Case 4

	Size	Number of blocks
Controller	404Kb	598
Plant model	-	

Numbers of blocks are investigated by using sldiagnostics('sys','CountBlocks').

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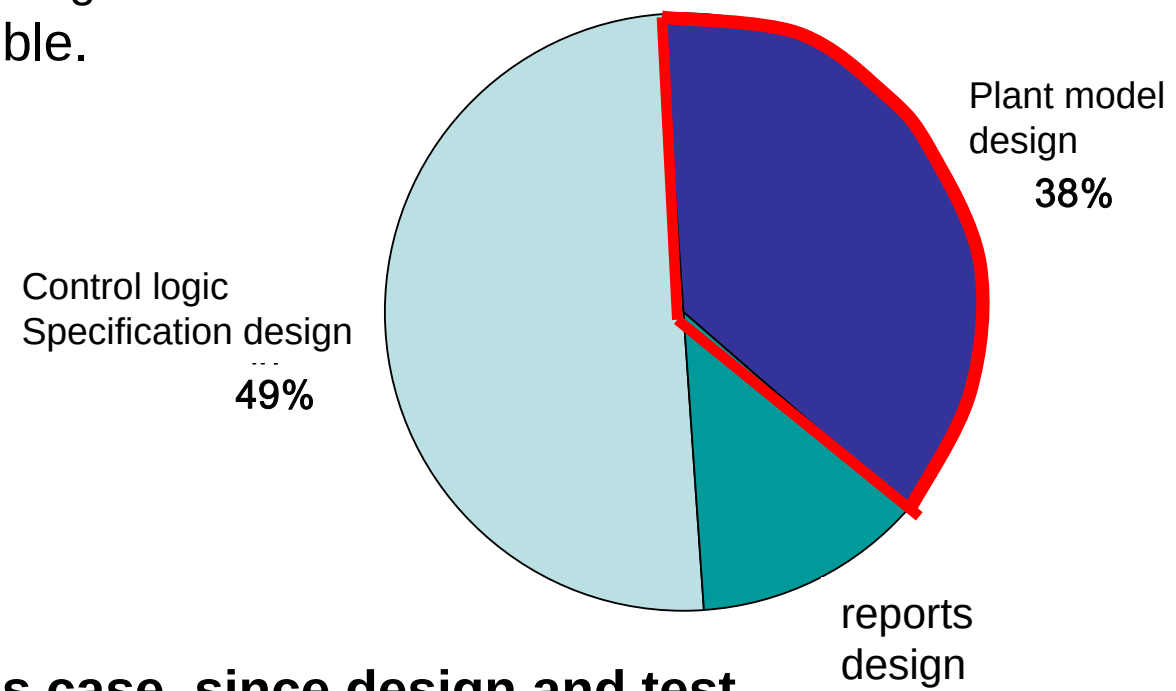
In control logic development, if plant model design takes long time, benefits of MBD become thin.
Since our main purpose is control logic design, we would like to make plant model design time as short as possible.

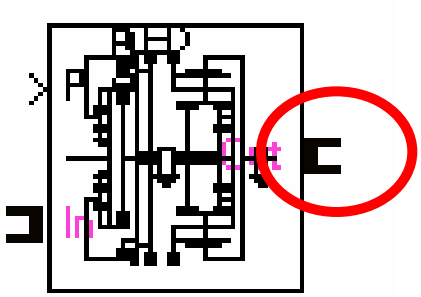
Man-hour ratio of control logic development (case 1)

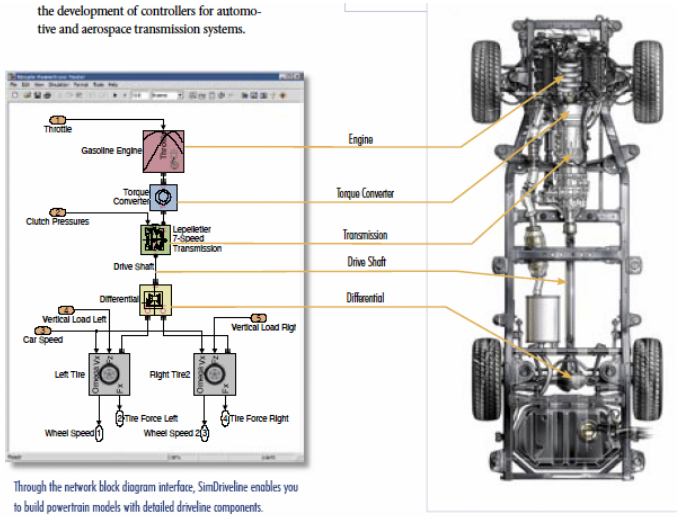


However, in this case, since design and test cannot be separated, their summation time is shown.

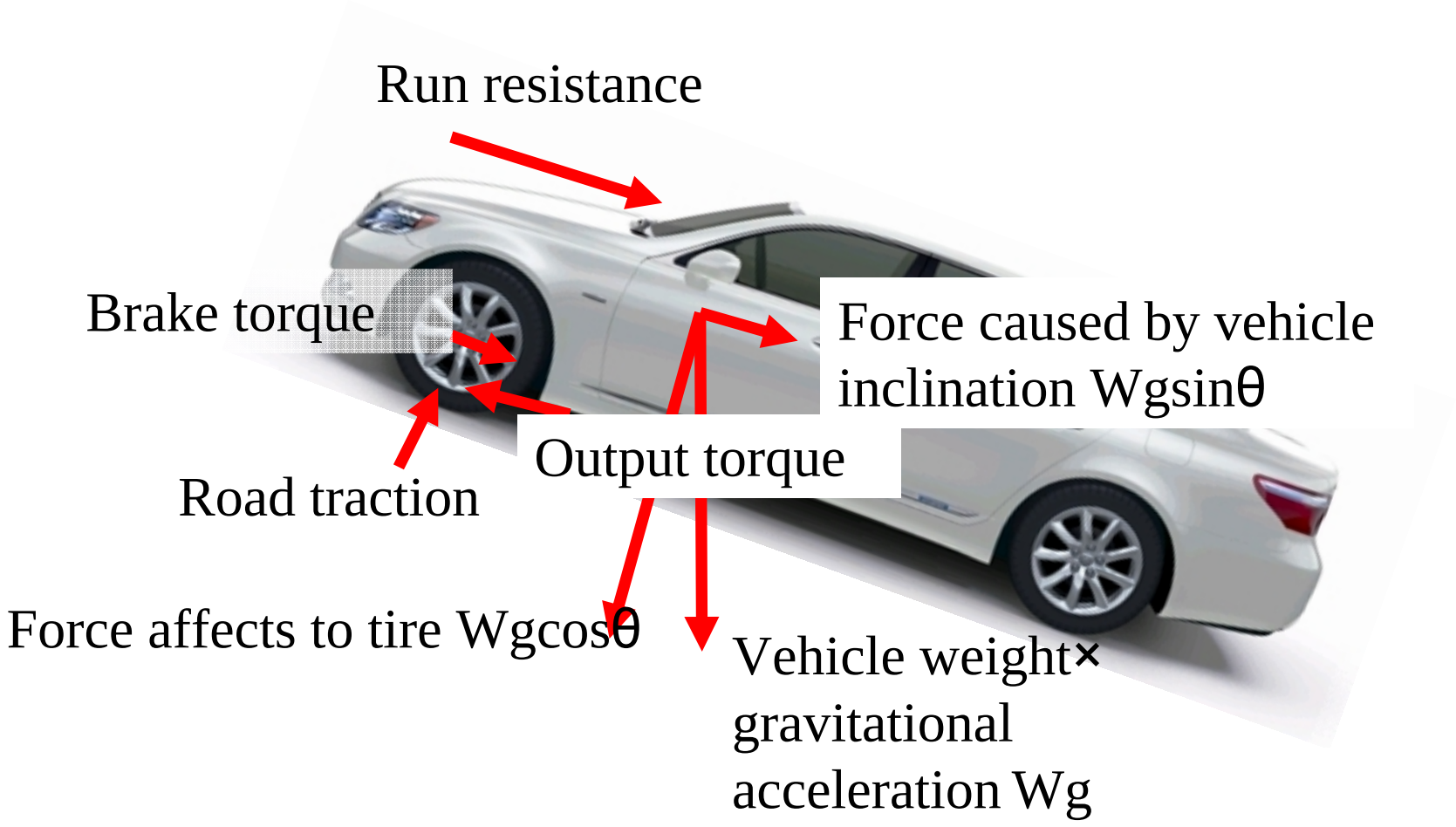
Merits of using SimDriveline

- SimDriveline is different from Simulink. By only combining icons, for example, planetary gear, complicated equations can be solved.
- By using SimDriveline, we could construct convenient plant model for Automatic Transmission control specification development in short time.

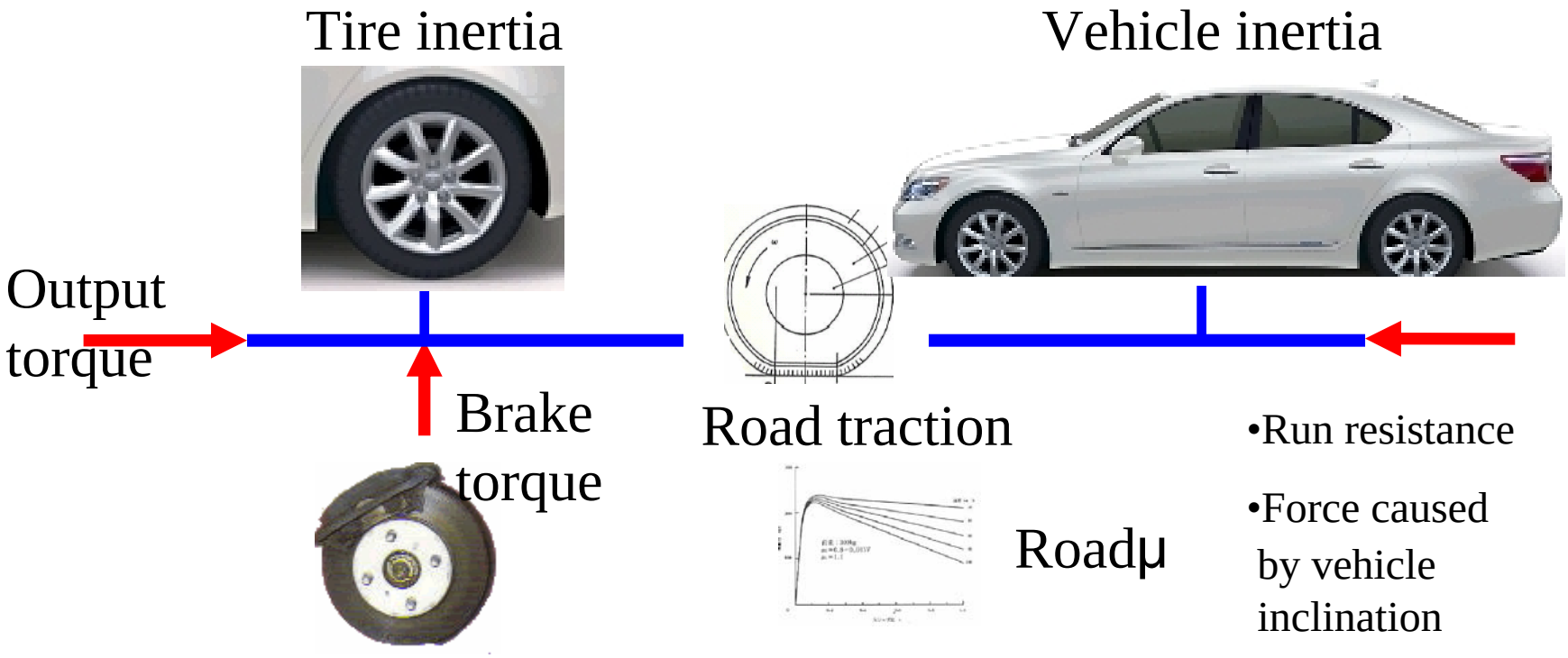




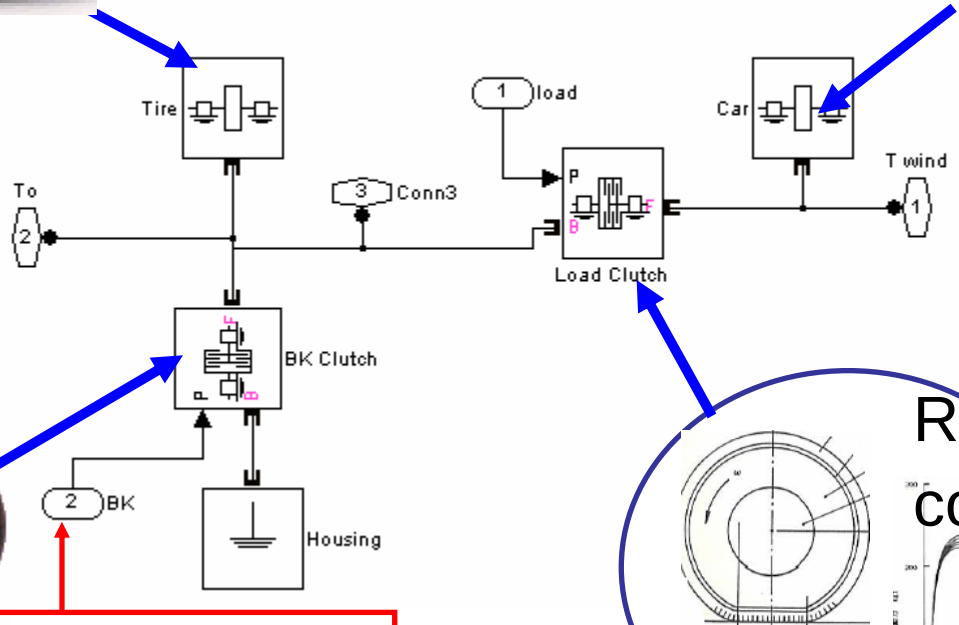
- About vehicle model

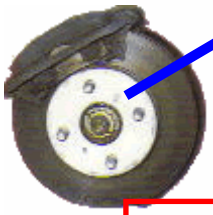


Vehicle modeling



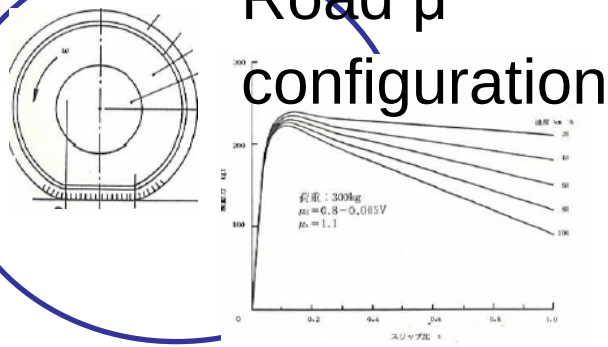
Vehicle model on SimDriveline





ABS controller model

Road μ configuration

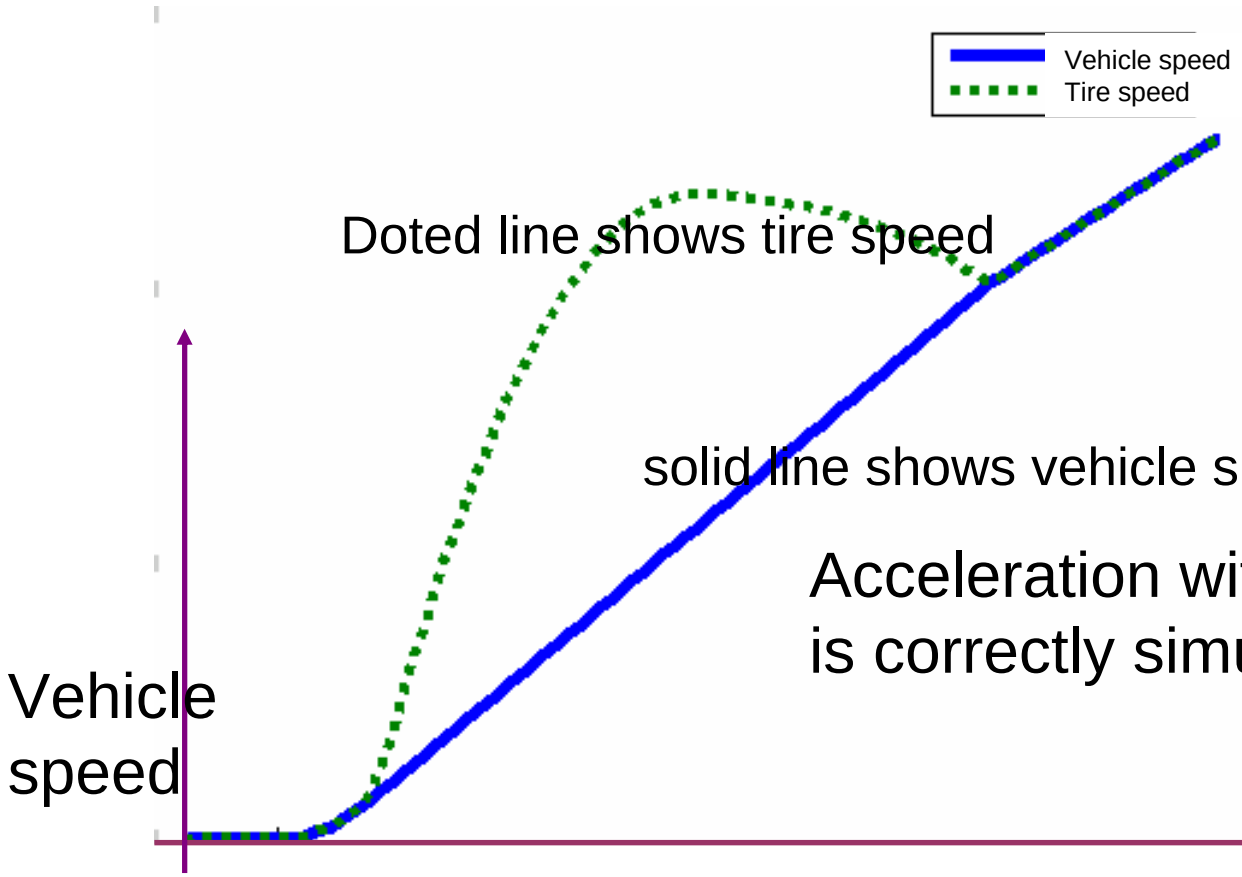


Tire slip simulation

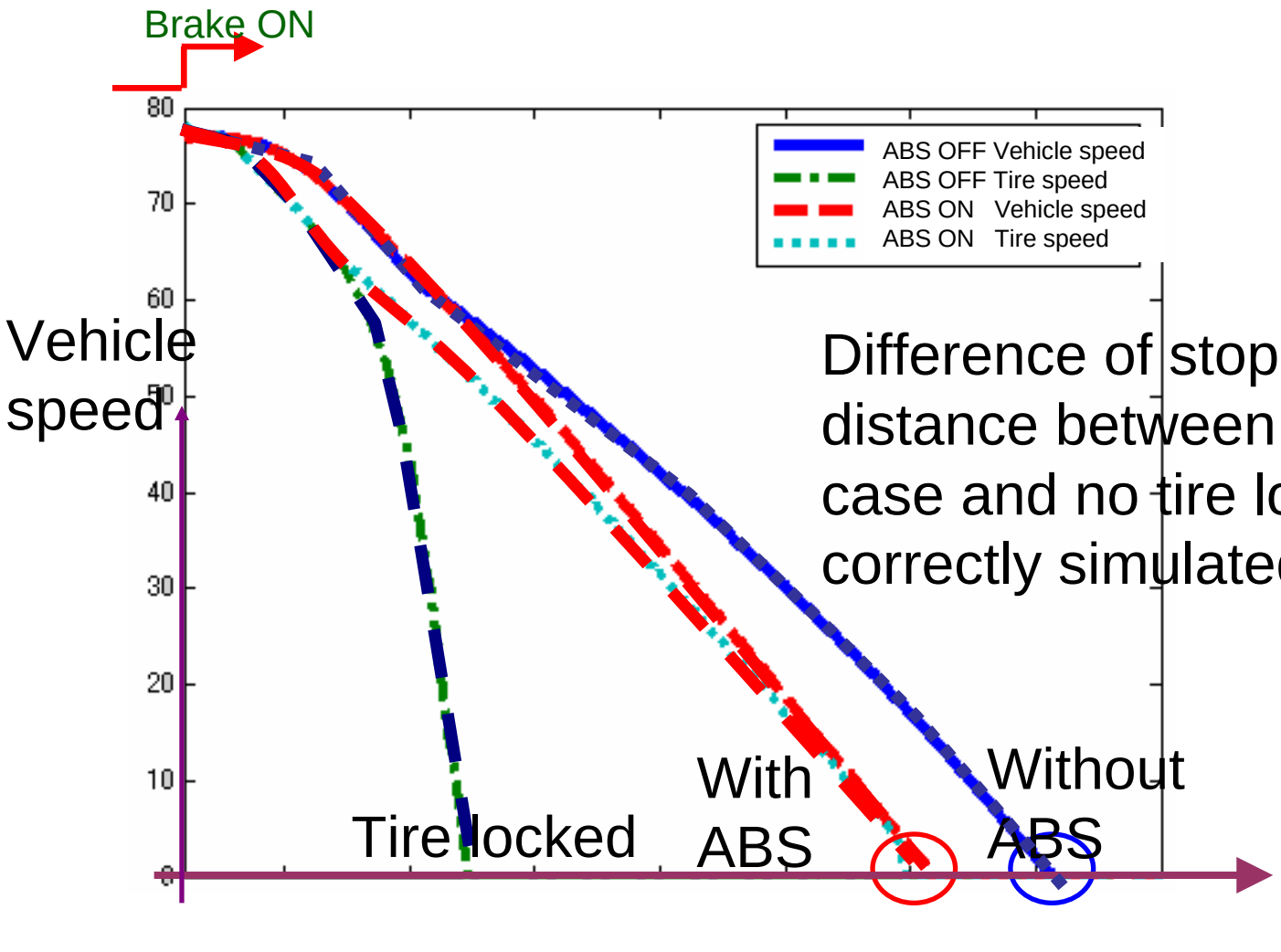
Solver : ODE1

Fixed-step

1000Hz



Vehicle stop simulation



Difference of stopping distance between tire locked case and no tire lock case is correctly simulated.

Simulation result shows that the case with ABS stops faster than the case without ABS.

- About examples of SimDriveline application, please refer materials of CDA seminar or MATLAB EXPO in 2005

About these materials, please contact to CYBERNET SYSTEMS CO.,LTD

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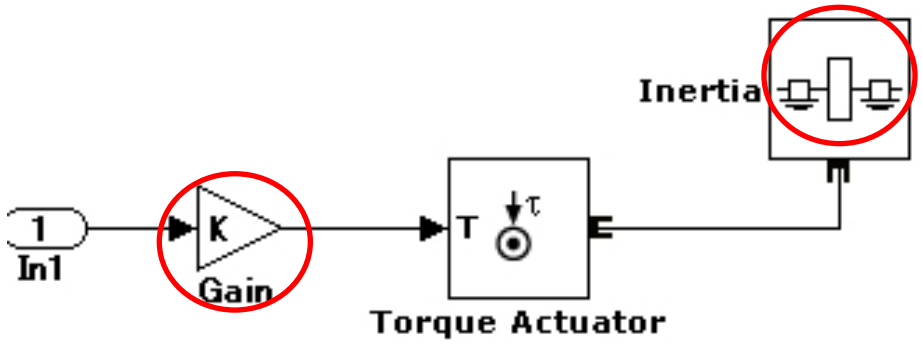
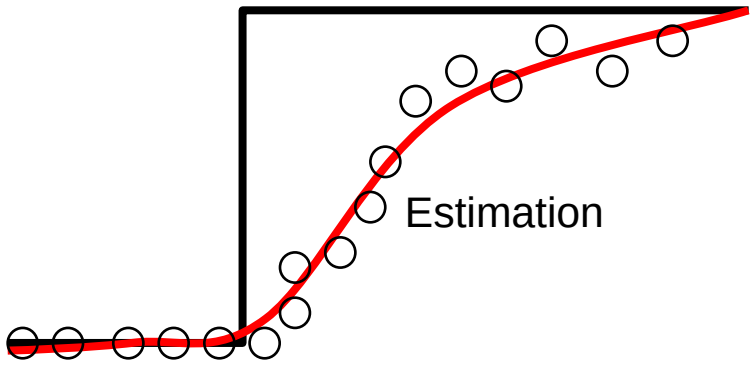
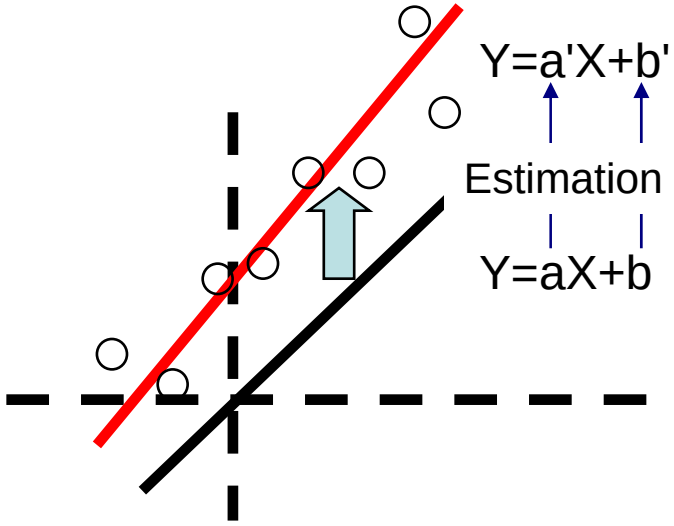
- An example of SimDriveline with Parameter Estimation combination.
  - By setting actual vehicle data to input and output for six-speed A/T model constructed by using SimDriveline, transmission efficiency, loss, inertia were calculated by Parameter Estimation.



- Parameter Estimation is different from general system identification tool. By using PE tool, optimal values of variables in equation can be calculated. Therefore, by using this tool, accuracy of existing plant model can be improved.

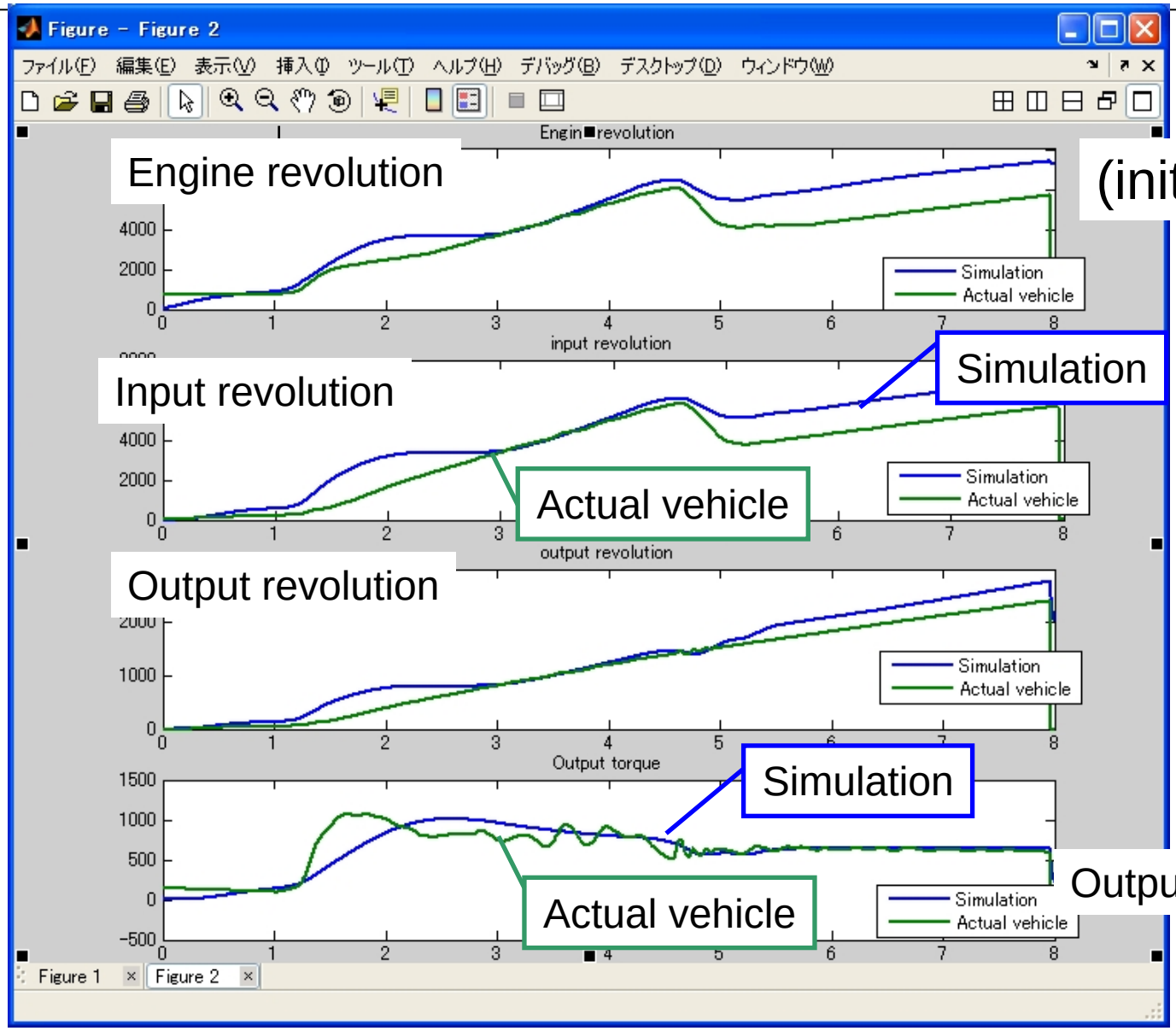


System Identification tool



Parameter Estimation

Without Parameter Estimation



Engine revolution

(initial value)

Input revolution

Simulation

Actual vehicle

Output revolution

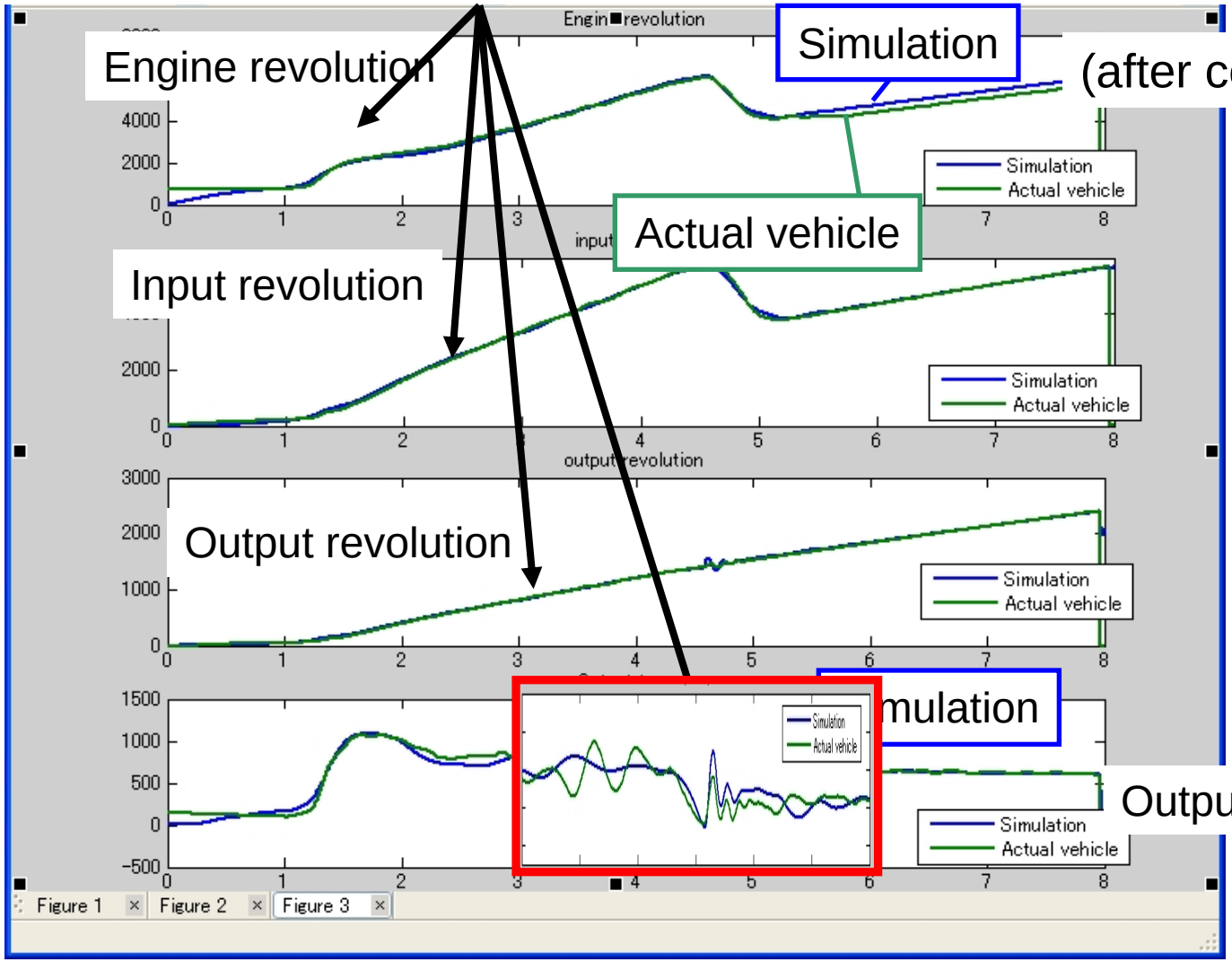
Simulation

Actual vehicle

Output torque

With Parameter Estimation

Estimate parameters to make these 4 simulation measurements accord with actual vehicle measurements.



Comparison of output torque waveform

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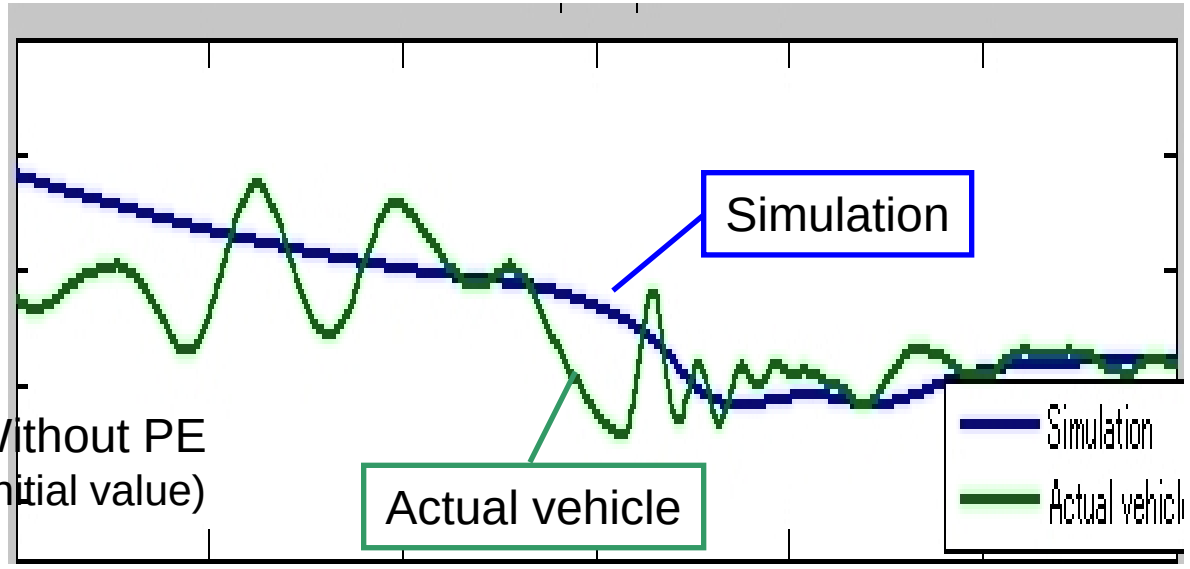
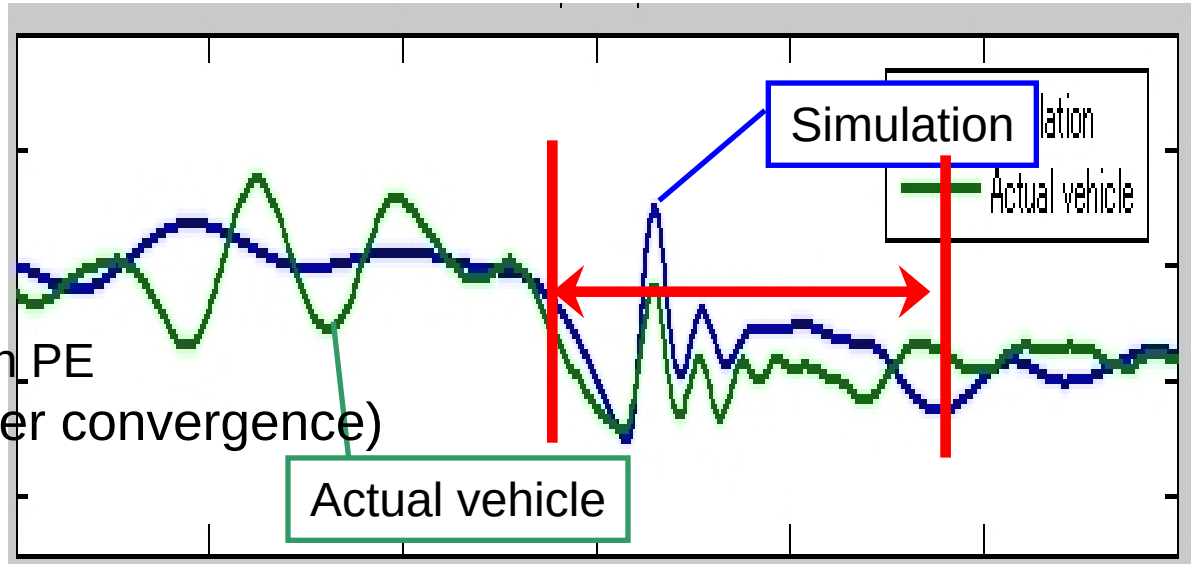


Without PE
(initial value)



With PE
(after convergence)

Table of estimation result

Variable	Without PE (initial value)	With PE (after convergence)
Inertia of inputting shaft	0.2	0.2241
A (T/M Efficiency)	1.0	0.8859
B	1.0	1.0652
C	1.0	1.1104
Stiffness of outputting shaft	300	10824
Damping of outputting shaft	10	60

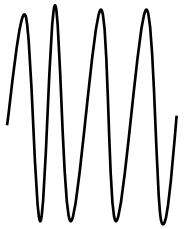
- Conventionally, unknown parameters were adjusted manually. However, by applying Parameter Estimation, optimal parameters were calculated easily.
- By combining Parameter Estimation and physical modeling tool, such as, SimDriveline, more efficient MBD application is possible. This combination will expand benefits of MBD.

Agenda

1. Introduction
2. Status of activities for Model Based Development
   1. H I L S *development*
   2. H I L S *engineer curriculum*
   3. MATLAB basic text
3. Control system development
   1. The first try to Control logic development
   2. NEW Control logic development
4. Plant model development
5. Examples of application
6. Expectations for SimDriveline
7. Activities for Automatic Code Generation (ACG)
8. Closing

1. Complete prevention of simulation stop
2. Function to calculate energy loss
3. Attaching simple hydraulic controller
4. Attaching simple hydraulic pressure circuit model
5. Increasing default gear trains
6. Adaptation of unit for torque converter to Japanese standard

- Before gear-shifting, after gear-shifting, and vehicle stop by braking cause simulation stop.
- In case of automatic test on HILS, simulation stop is critical defect.



Dumper added only to prevent simulation stop is meaningless

Dumper shall be used when simulation which includes shaft stiffness is executed.

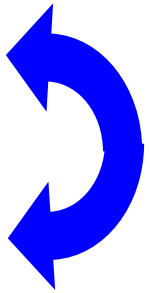
6.2 Function to calculate energy loss

3 June 2008

- About planetary gear efficiency calculation, when input and output are reversed, efficiency also changes. Therefore, correct torque efficiency cannot be calculated currently.
- By adopting method to transform meshing losses of gears to thermal loss and so on, system to calculate transmission efficiency correctly is expected to be implemented.

Written on Jidousya-Gijyutsu handbook
P235

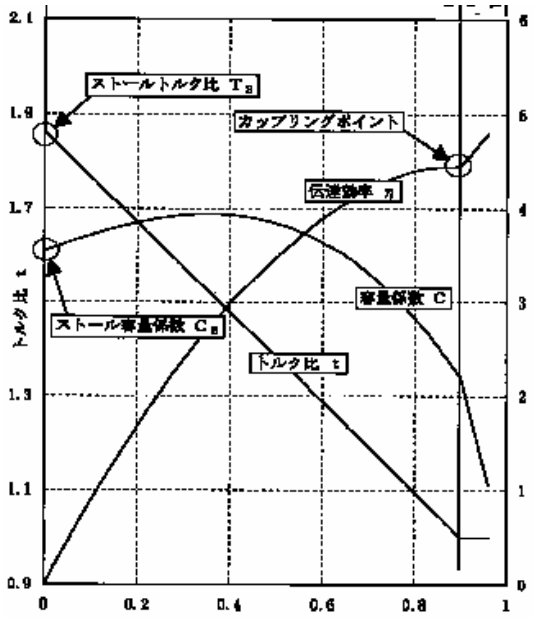
Input	Output	Fixed	Efficiency
Ring gear	Carrier	Sun gear	(1+ρ ηO)/(1+ρ)
Carrier	Sun gear	Ring gear	ηO(1+ρ)/(1+ρ ηO)
Carrier	Ring gear	Sun gear	ηO(1+ρ)/(η O+ρ)
Sun gear	carrier	Ring gear	(η O+ρ) /(1+ρ)



While capacity factor which is set up by JSAE cannot use, data cannot be implemented to SimDriveline.

	SimDriveline	JSAE
Capacity factor	rad/s/sqrt(Nm)	N・m/rpm^2 ×10^{-5}

Written on Jidousya-Gijyutsu handbook P219



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- There is much work to be done by manually.

  Problems of Automatic Code Generation

  – Options must be configured. If option configuration is forgot, generated code becomes different from guessed one. And it takes long time to investigate cause of differences.

  – By customizing, expected C code can be generated. However, we don't read generated code. Currently, much man-hour is spent customizing C code which is not read.

If expert engineer does all work alone, there is no problem. However, for novice, amount of works to do is too much. Therefore to retain code quality becomes difficult.

Goal

- Our target concept for ACG is to have complete automatic process including checking for the generated code.
- As a rough estimation, deeper investigations on the following two items are necessary.

1. Testing
   - Automatic verification and validation by using Simulink Design Verifier is planned.
2. Quality checking for generated code

Key-points from now are as follows

- Automate simple works as much as possible.
- Quality assurance by using model checker.
- Confirmation of defect detection ability of static code checker, PolySpace and so on.

Within a few years, we will build up the system which can generate high-quality code even by beginner

- Our activities for MBD were introduced.
- Our control logic developments were introduced.
- Practical use examples of Plant model were introduced.
- Expectations for SimDriveline were shown.
- Our activities for Automatic Code Generation were introduced.

Since this presentation includes some confidential matters, if there is some question, please ask by e-mail via The Math Works.