SPLC2013

August,29,2013

Innovation of automotive software development

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DENSO CORPORATION

DENSO

Company Profile

Established	December 16, 1949
Capital	187.4 billion yen (US$2.0 billion)
Net sales	
Consolidated basis	3,580.9 billion yen (US$38.1 billion)
Non-consolidated basis	2,276.8 billion yen (US$24.2 billion)
Net income	
Consolidated basis	181.7 billion yen (US$ 1.931.8 million)
Non-consolidated basis	146.0 billion yen (US$ 1.552.8 million)
Employees	
Consolidated basis	132,276
Non-consolidated basis	38,385
Consolidated subsidiaries	183
(Japan 62, North America 28, Europe 34, Asia/Oceania 53, Others 6)	
Affiliates under the equity method	32
(Japan 13, North America 4, Europe 2, Asia/Oceania 11, Others 2)	

Notes:
U.S.dollar amounts have been translated, for convenience only, at the rate of 94.05 yen = US$1,
the approximate exchange rate prevailing on March 31, 2013. Billion is used in the American sense of one thousand million.

/ as of March 31, 2013

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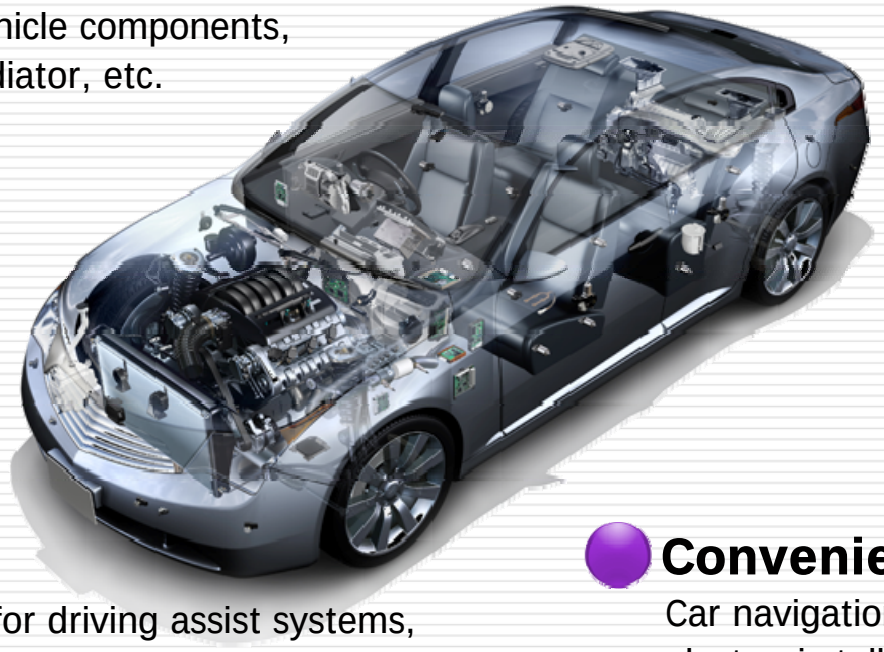
Main Products

Environment

Gasoline engine management system,
diesel engine management system,
hybrid and electric vehicle components,
starter, alternator, radiator, etc.

Comfort

Car air conditioning system,
air conditioner for buses, air purifier, etc.



Safety

Sensing technologies for driving assist systems,
actuator & computer for antilock brake system (ABS) /
electronic stability control (ESC),
adaptive front-lighting system (AFS),
airbag sensors & electronic control units,
periphery monitoring system, instrument cluster,
rain sensor for automatic windshield wiper, etc.

Convenience

Car navigation system,
electronic toll collection system (ETC),
remote security system,
remote touch controller, smart key,
advanced vehicle operation system (AVOS),
etc.

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Challenges surrounding Mobility Society

Global Environment

- Contribution to developing an environment friendly to the earth
- CO2 reduction, fuel efficiency improvement and diversification of energy sources to prevent global warming
- More electric(Hybrid, PHV, EV) Change from Engine to Motor

Traffic Safety

- Realize Zero-traffic accident society
- Pre-crash safety ～ Active safety～ Drive assist
- Make existing products low cost for wider spread and develop further advanced safety device

PHV: Plug-in Hybrid
EV: Electric Vehicle

Future Society

- Energy collaboration with homes and local communities
  - ✓ PHV,EV to Smart grid, Micro grid
- Semi-automatic drive by coordination with infrastructure (Vehicle-vehicle, Road-vehicle)
- Utilization of IT･Cloud by broadband connection
- Change of the usage style of the car
  - ✓ Car sharing, Multi modal

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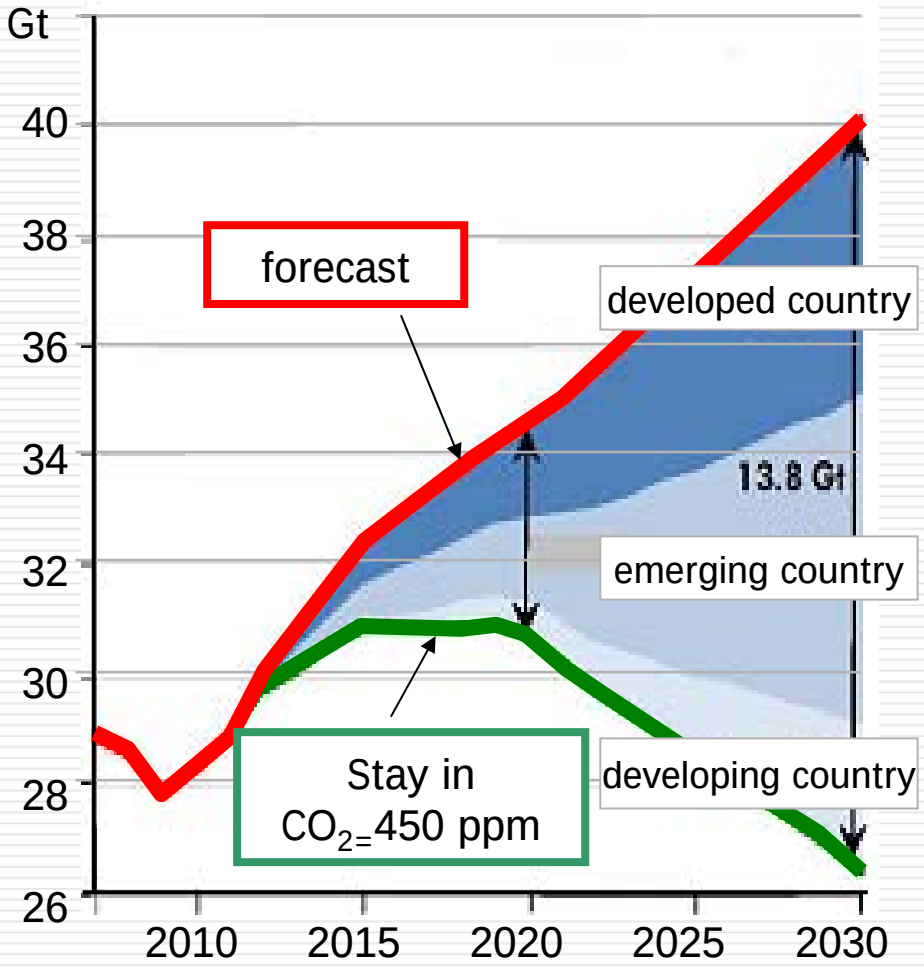
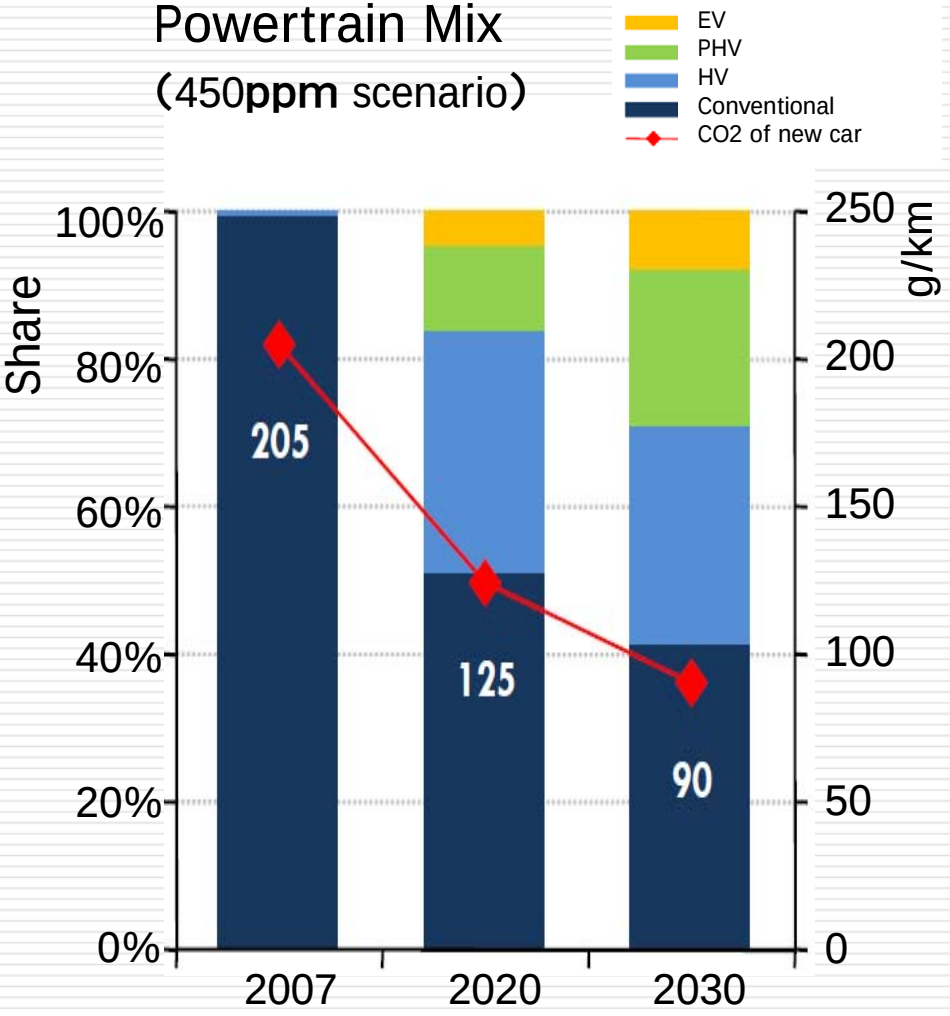
Global environment：Global warming and counter measures

Forecast of CO_2 emission



Powertrain Mix

(450**ppm** scenario)



Source：World Energy Outlook 2009, IEA

CO2 free / Low CO2 emission vehicle will expand

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Safety - traffic accident fatalities in global and Japan

Traffic fatalities in global

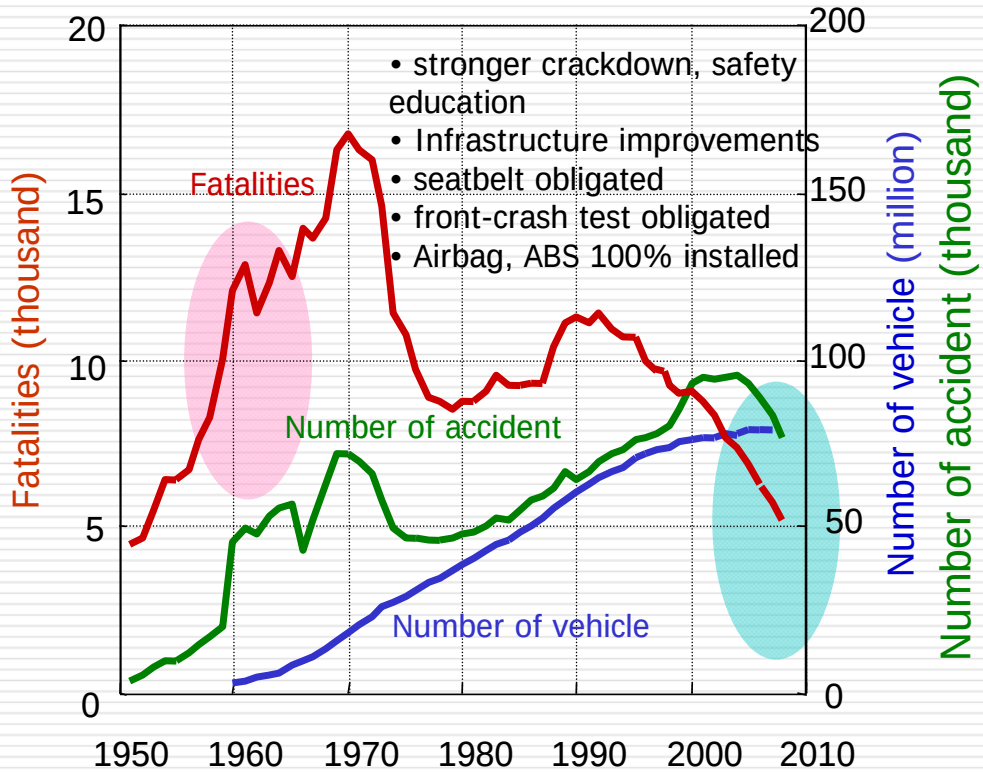
(thousand)

	1996	2009	trend
JAPAN	9.9	4.9	↘
U.S.A	42.1	34.0	→
EU 25	55.5	39.1 ('07)	→
China (PRC)	73.7	67.8	→
India	74.7	114.4('07)	↗
SE Asia	32.2	36.5('07)	↗
Brazil	5.3('98)	7.1 ('07)	↗
World	1170.7 ('98)	1270.0('04)	→

(Source)

- Based on various statistical data in 2009
  (Exhibited by: Global status report on road safety (WHO), European Road Statistics 2009 (IRF), Transportation conditions report of major countries(MLIT), NPA, NHTSA, The Ministry of Public Security of the People's Republic of China.)
- EU: 25 countries (excepted Bulgaria, Romania from EU-27)
- South-Eastern Asia: Philippines ('06), Malaysia ('07), Singapore ('07), Indonesia ('07), Thailand ('07)

Traffic fatalities in Japan



ABS: Anti-lock Brake System
ESC: Electronic Stability Control

Emerging country is similar to 1960s Japan ⇒ Demanding Airbag, Seatbelt, ABS/ESC
Airbag, ABS/ESC already spread in JP,US,EU ⇒ Demanding ADAS (Advanced Driver Assistant)

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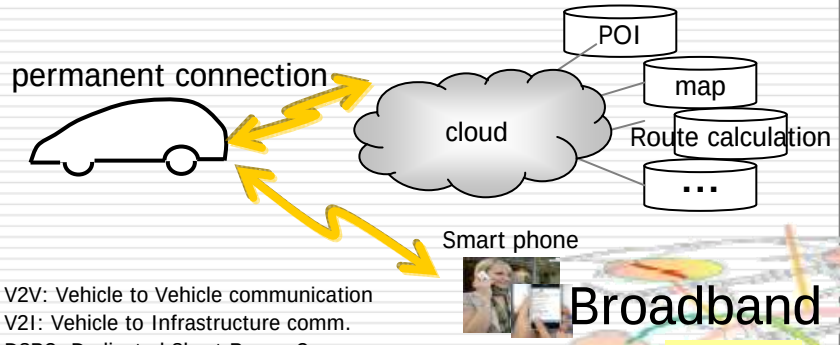
Future Society：Mobility society image

Ubiquitous Society

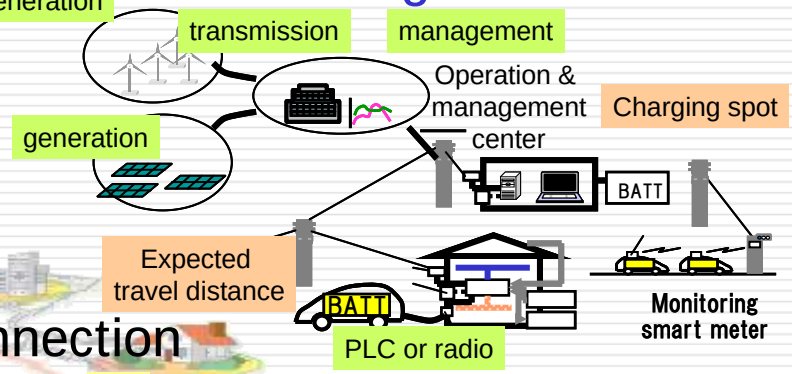
Anyone, Anytime, Anywhere : enjoy various services through network without any stress.

Widespread use of IT services



V2V: Vehicle to Vehicle communication
V2I: Vehicle to Infrastructure comm.
DSRC: Dedicated Short-Range Comm.

Smart grid

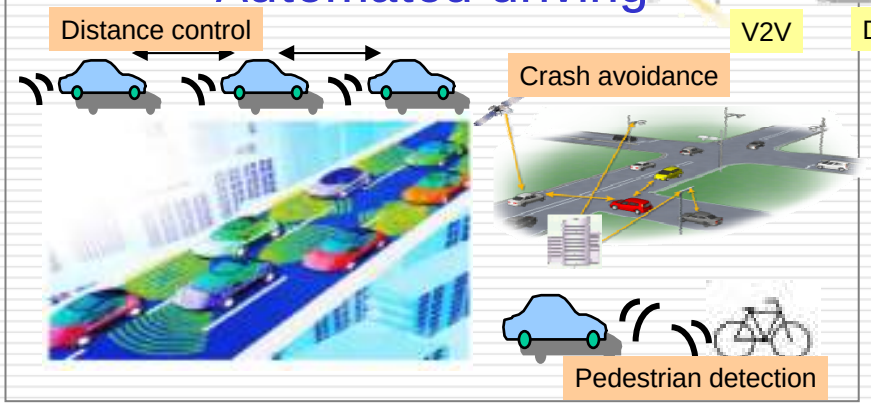


PLC: Power Line Communication

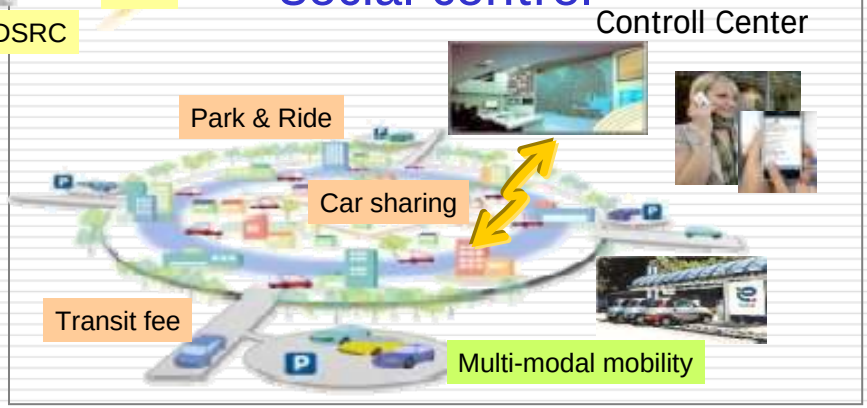
Broadband connection

cellphone network
V2I
WiFi
V2V
DSRC

Automated driving



Social control



New mobility society in cooperation with social infrastructure

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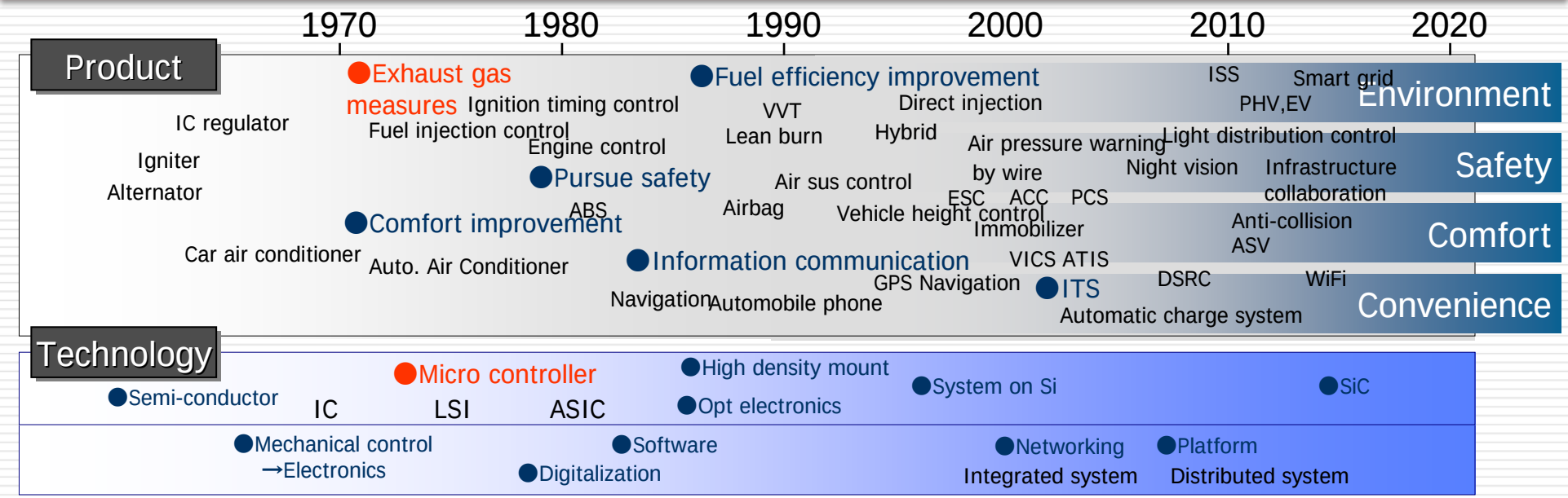
History and areas of car electronics

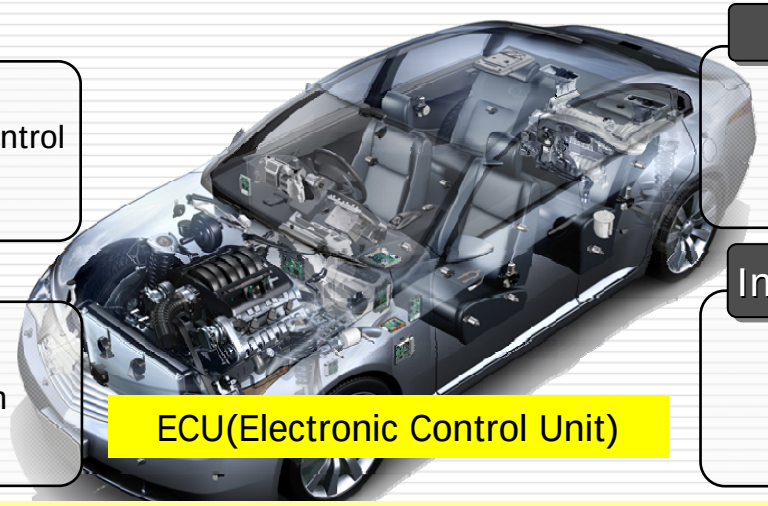


Power train control

- Engine control system
  - —Gasoline and Diesel engine control
- Transmission control system
- HEV/PHEV control system

Chassis control

- Power steering control system
- Electronic control brake system
- Drive assist system



ECU(Electronic Control Unit)

Body control

- Air Cond. system
- Air bag system
- Smart entry
- Security system

Information communication

- Car navigation system
- Automotive phone
- ETC system
- Audio system

Importance of electronics system is ever growing

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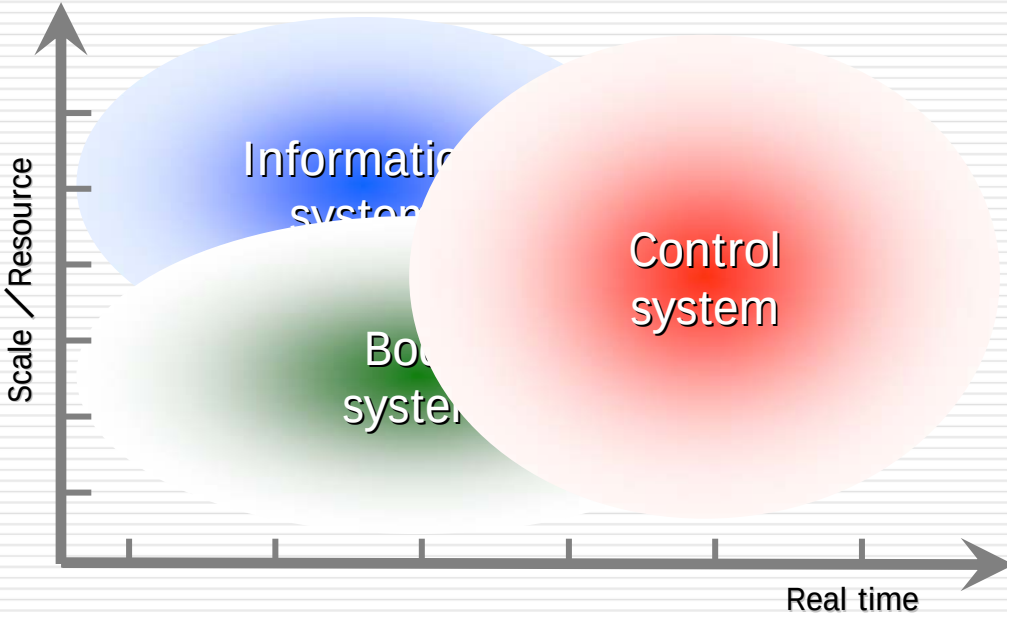
Characteristics of automotive embedded software

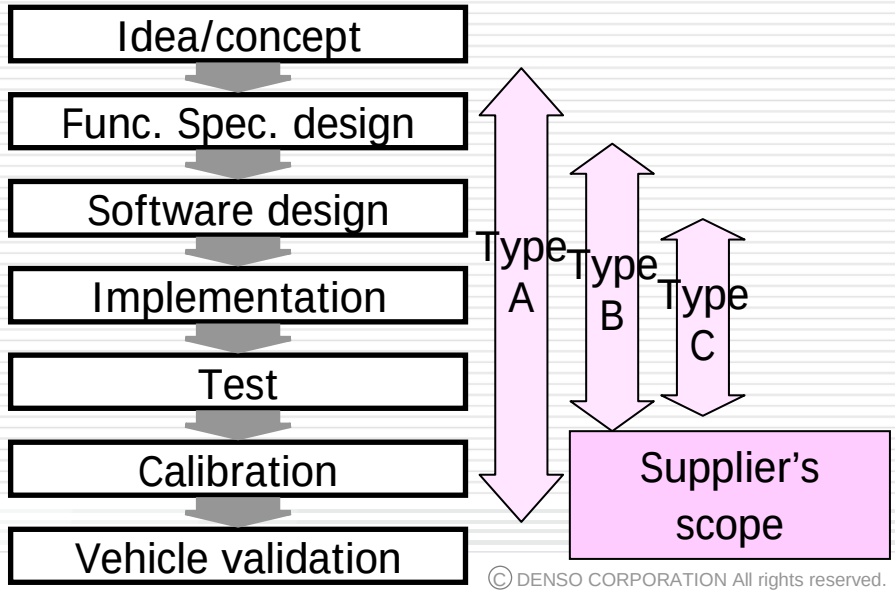
Product

- High quality
  - Functionality・reliability・efficiency (+ usability・maintainability・portability)
- Hard real-time
- Resource optimization
- Difference in domains
  - Control, body, information system



Process

- Division of development scope with automotive manufacturers
  - Development based on coordination
- Synchronization with vehicle development cycle
  - Verification using vehicle and bug fixing
- Many variations
  - Local laws, regulations, options
  - Continuous functional improvement



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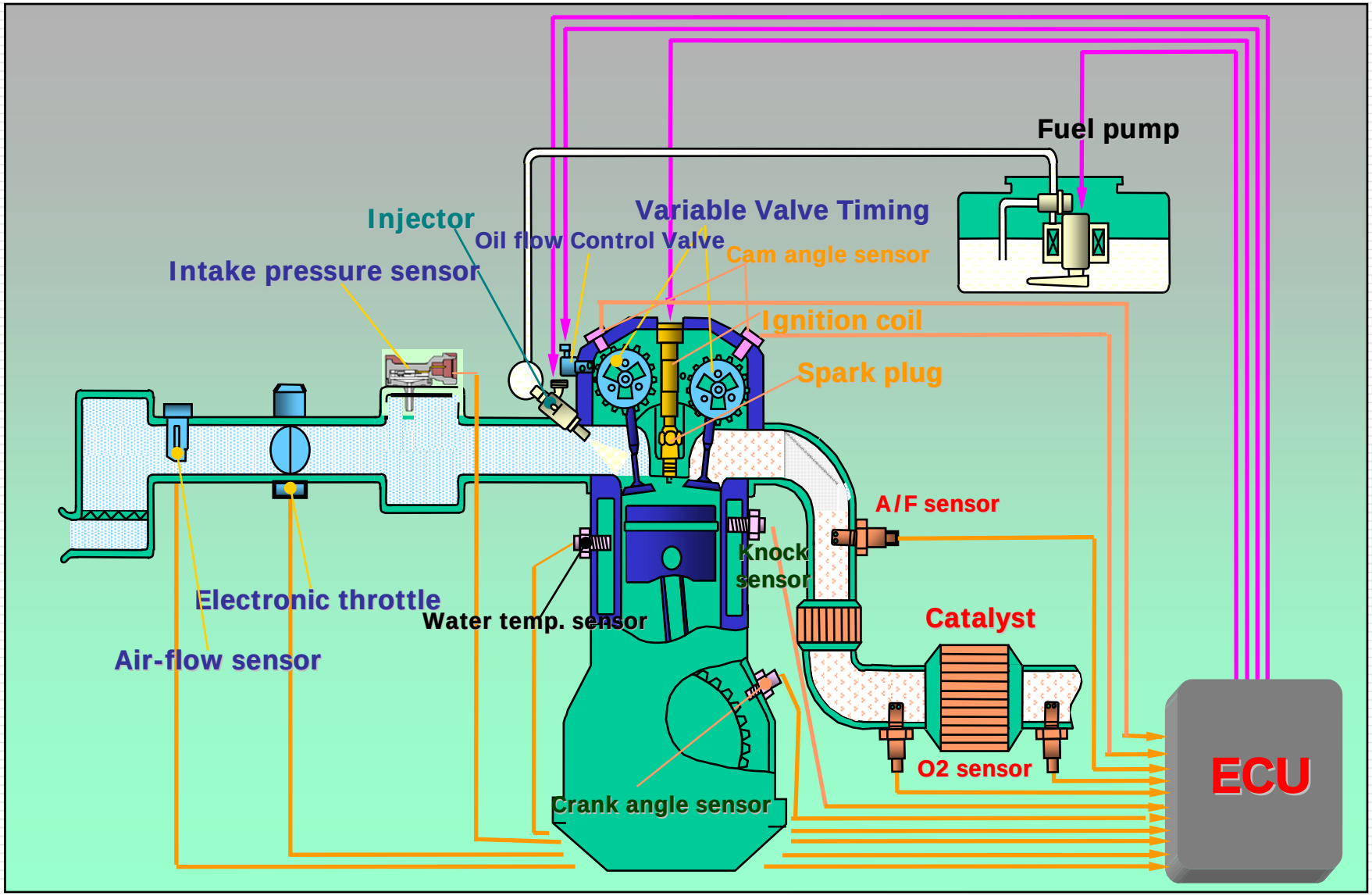
Example Gasoline Engine Control System



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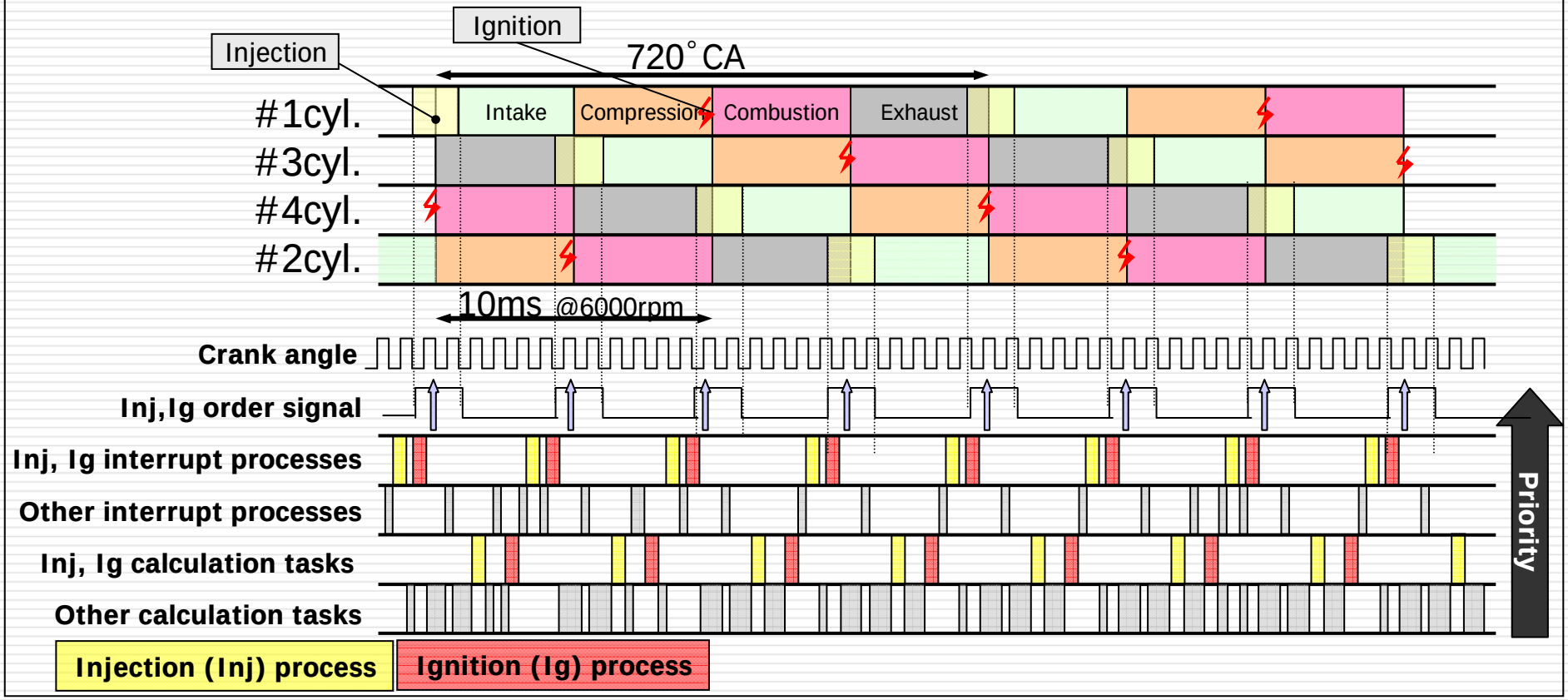
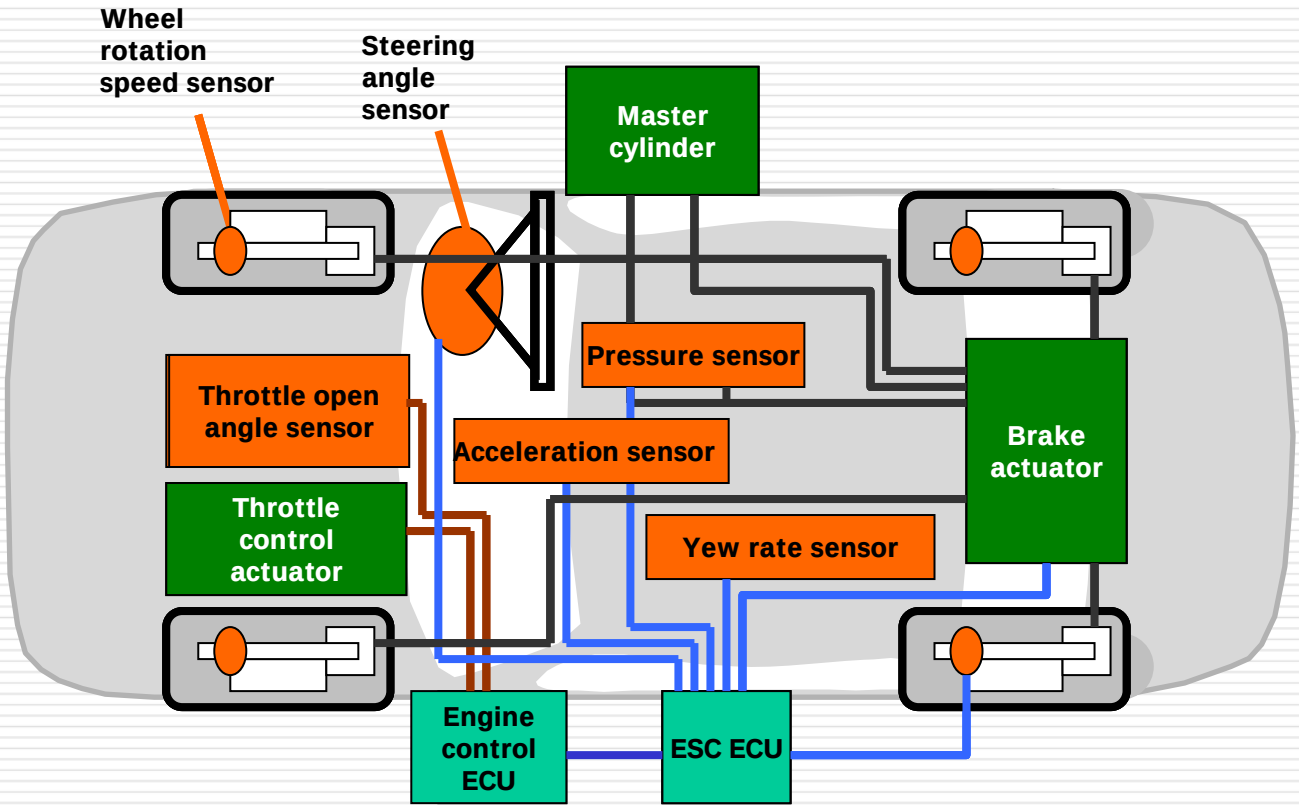
Example Gasoline Engine Control System

Simple sample of Gasoline Engine control



Examples　Electronic Stability Control

ESC (Electronic Stability Control) includes ABS (Anti lock Brake System), TRC (Traction Control), which is based on the wheel rotation sensor signal that detects wheel rotation condition.



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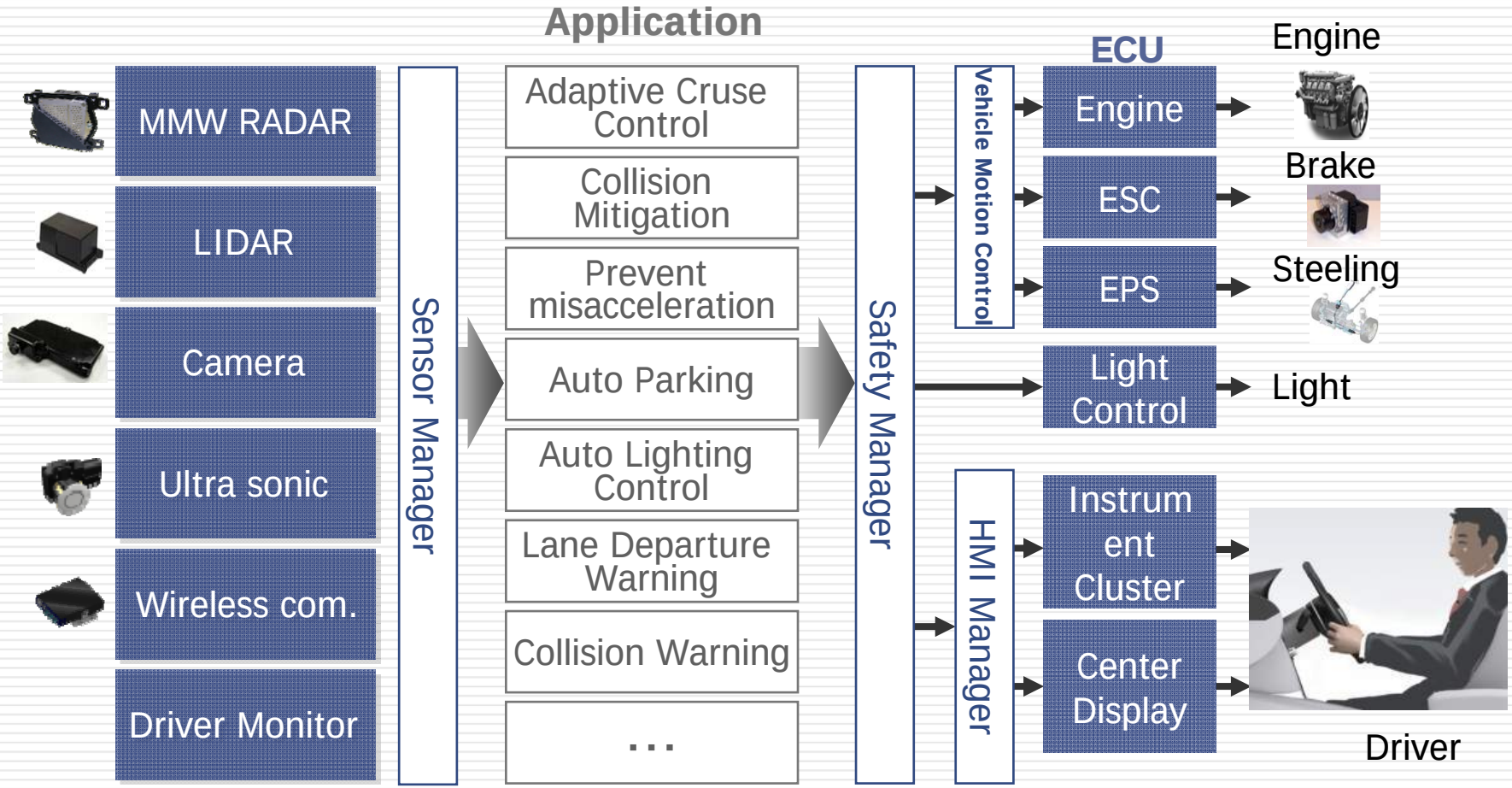
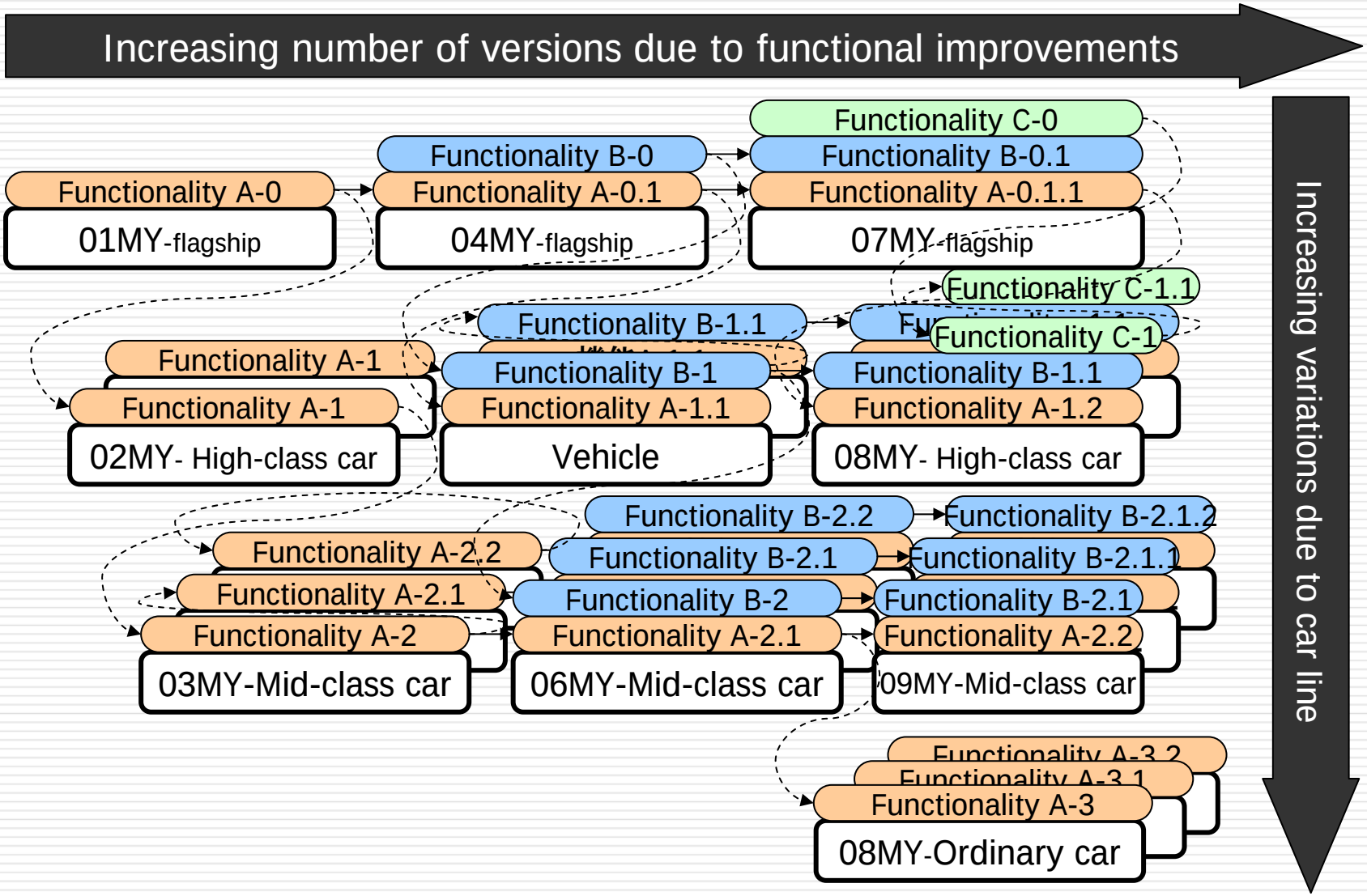
Example ADAS (Advanced Driver Assist System)



Automotive embedded software development



A large number of similar but different software is developed

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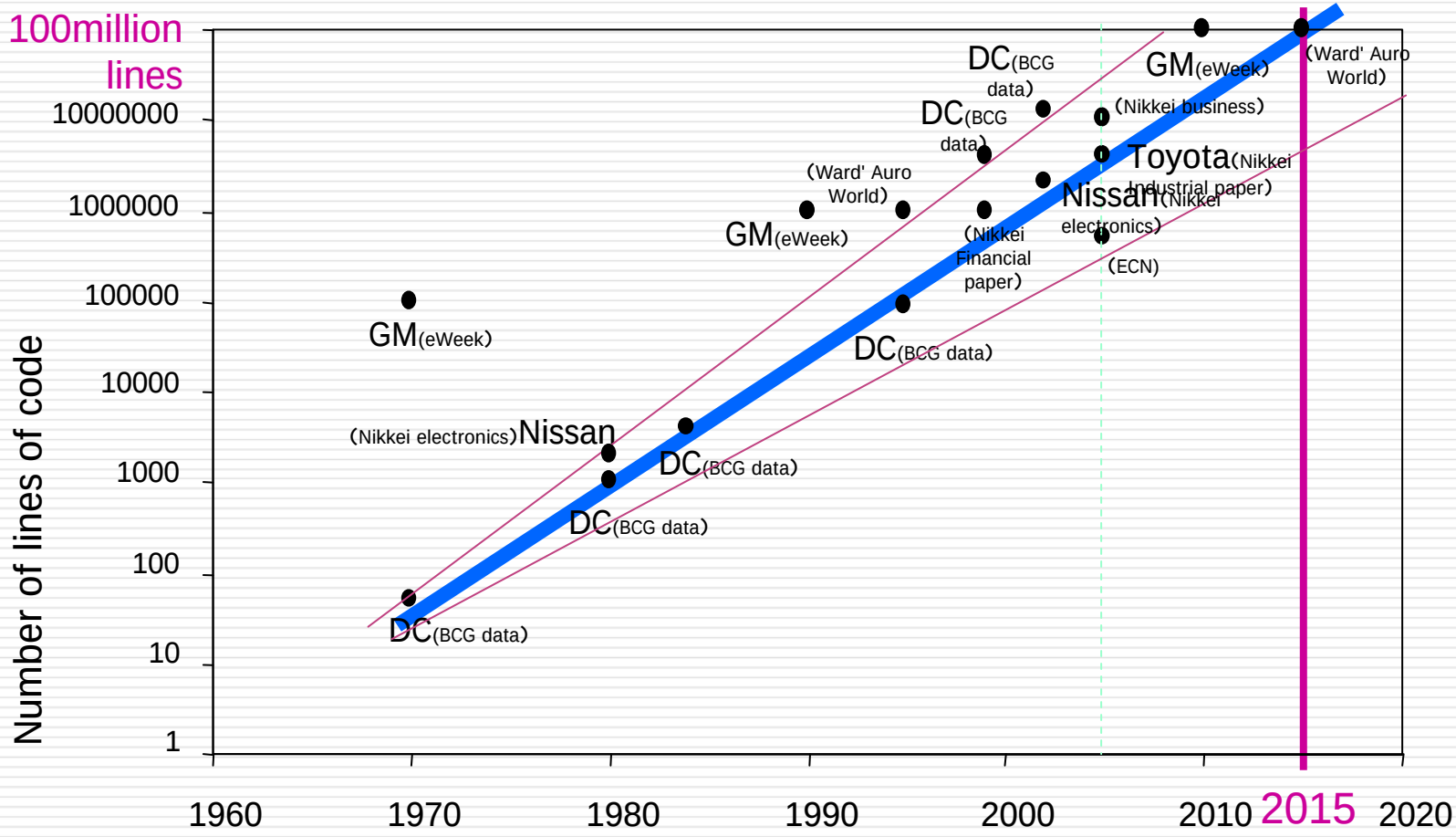
Transition in scale of automotive embedded electronic systems



Note:OEM names and data sources are specified in the chart . Data sources are in ( ). Source:Article search, BCG database and analysis

The number of lines of code is estimated to reach 100 million in 2015

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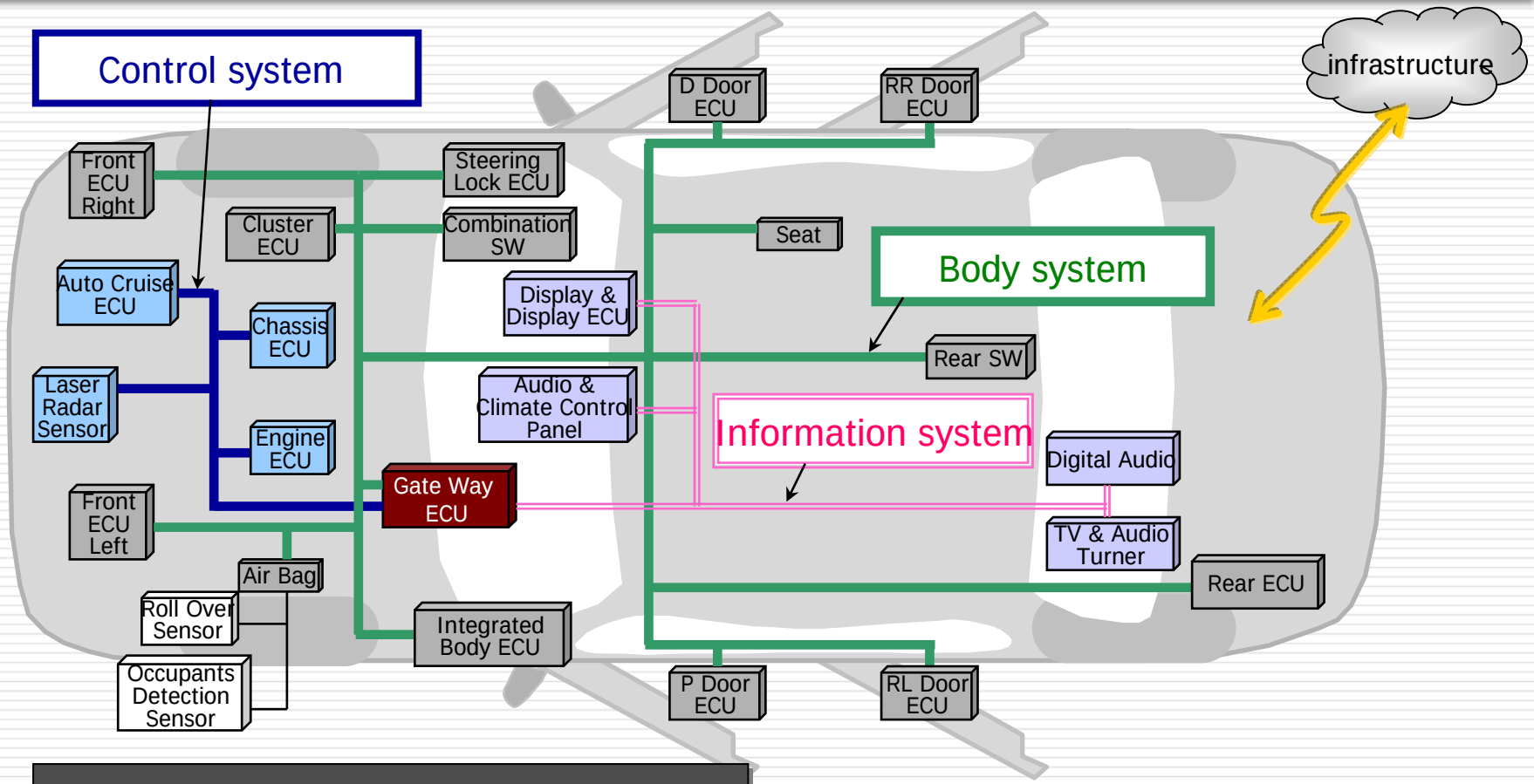
Vehicle network



Typical automotive communication protocol

■ Control system	: (mid ～high speed)	CAN, FlexRay
■ Body system	: (low speed)	CAN, LIN
■ Information system	: (high speed)	MOST, IEEE1394, Ethernet

Network for three different systems based on required bandwidth, and broadband connection will become more common

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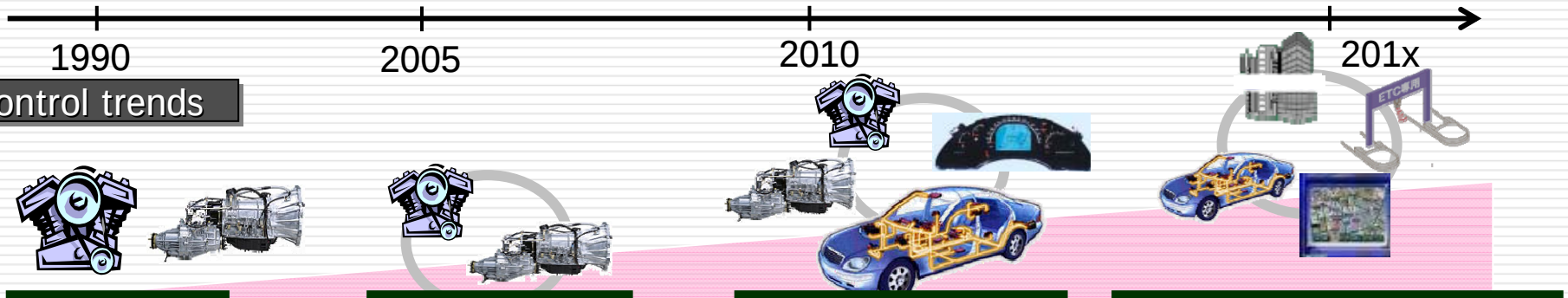
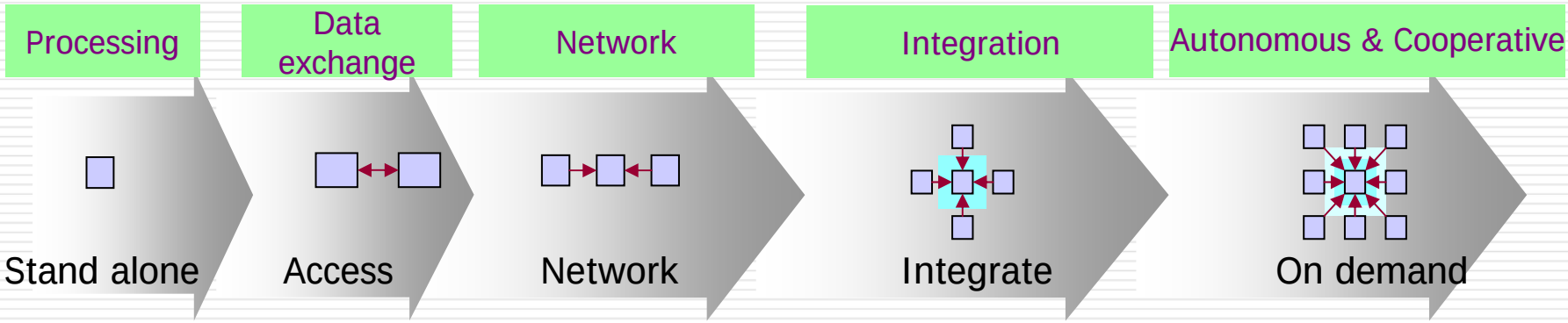
Transition of vehicle electronic systems

Control trends



(Ex.)Engine control → Vehicle motion integrated control → Driver assist integrated control→ Automated drive

ECU system



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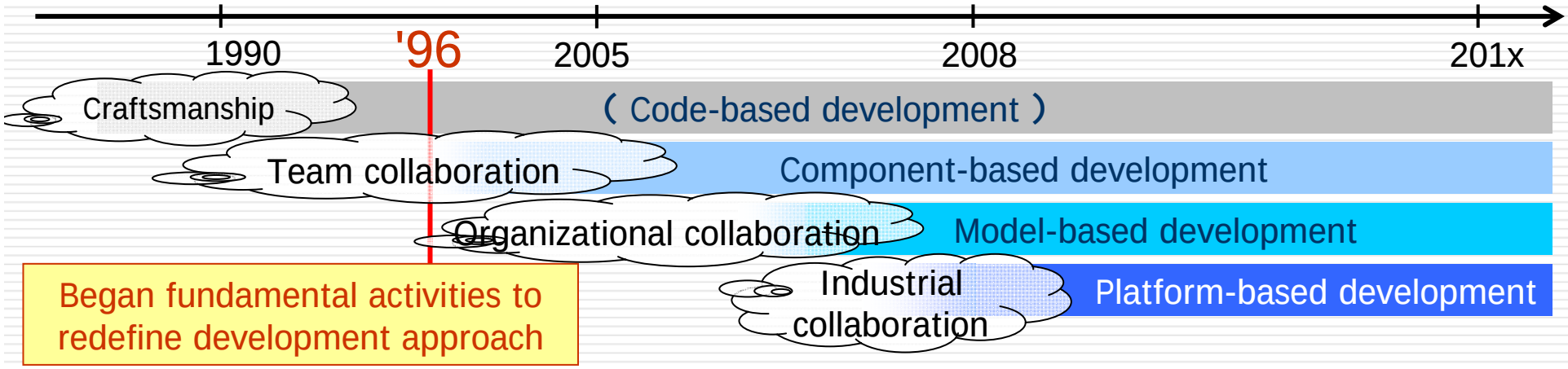
Transition in DENSO approach



DESCARTES Project

(***DE**velopment of **S**oftware **C**omponents, **AR**chitecture, **T**echnology, **E**nvironments and **S**ystems)*

Scale changes results in quality changes.

	Small scale software	Large scale software
Aim	Pursue improvements in cost and performance through craftsmanship Improvement of existing function	Pursue improvements in quality and efficiency through work split and collaborations. Creation of new values by functional collaboration
Development approach	Assembler, C language	Technological methods, architecture
Management approach	Quality management focused on individual skills	Organizational quality management using standard processes
Perspective	Product-oriented individual optimization	Optimization as a whole aiming at standardization, Right person in the right place

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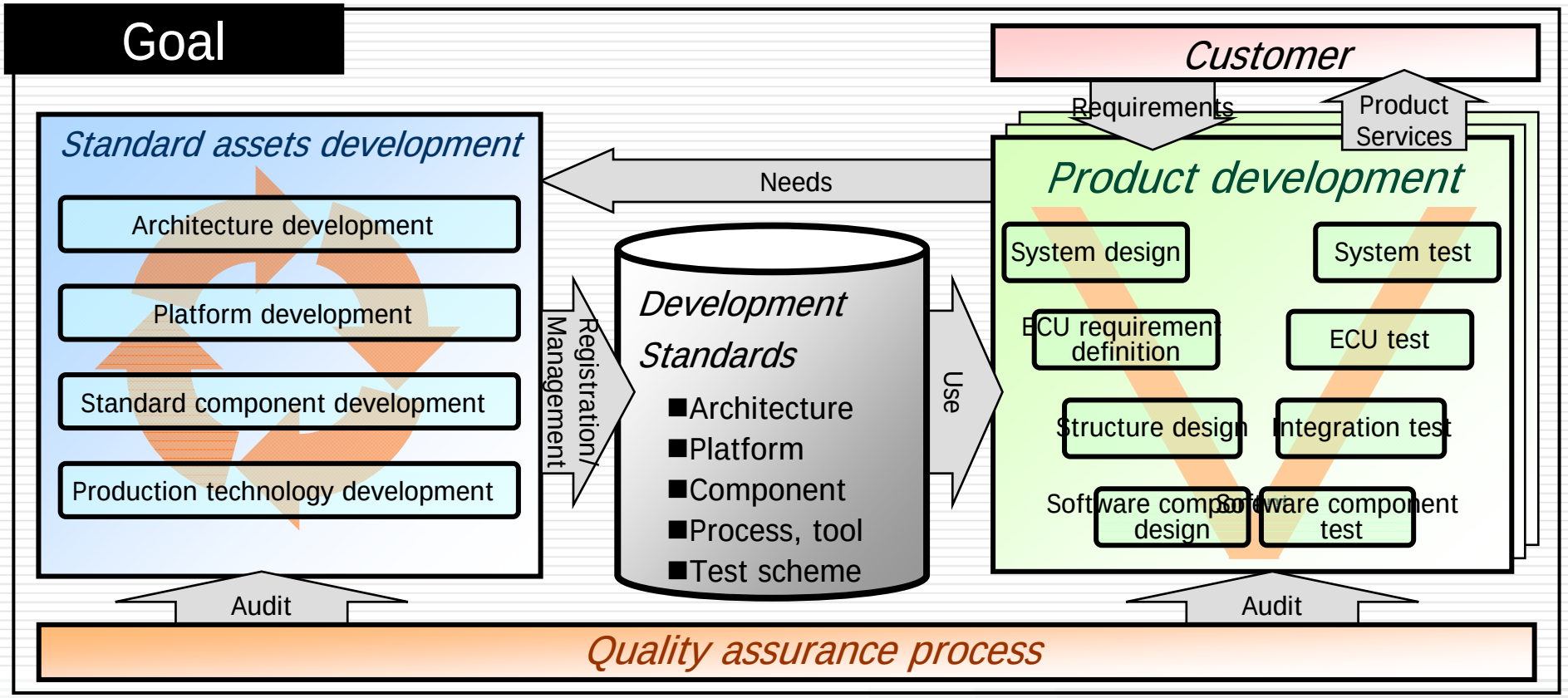
Basic idea of our approach

In order to develop a large number of similar but different software with high quality and productivity

Total optimization by reuse

◆Architecture : Hierarchical and modularized units for reuse.

◆Process : Collaborations for standard assets development and product development



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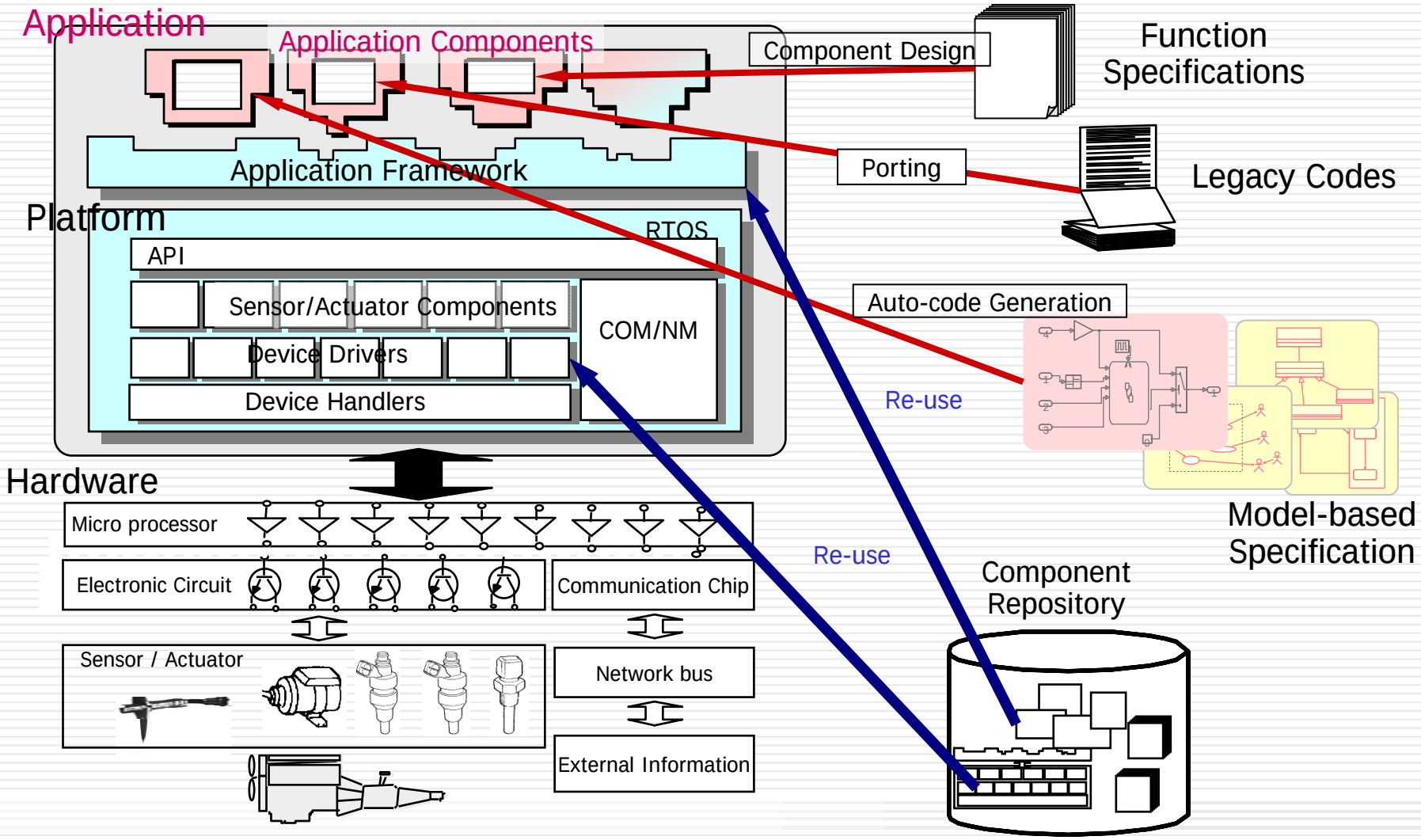
Contents

Component-based development(1)

Hierarchical and modularized units for reuse



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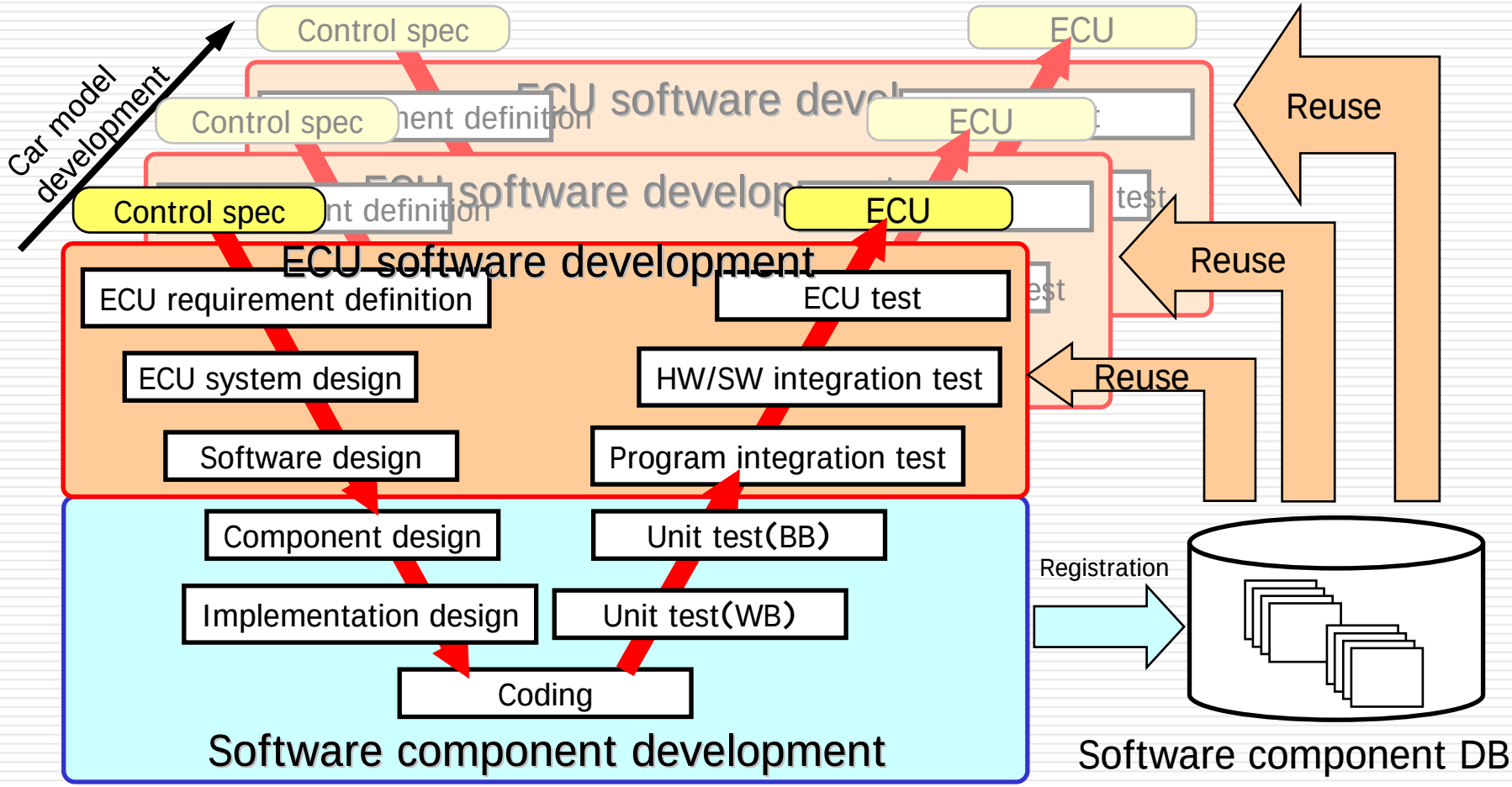
Component-based development (2)

Work split between software component development and assembly processes

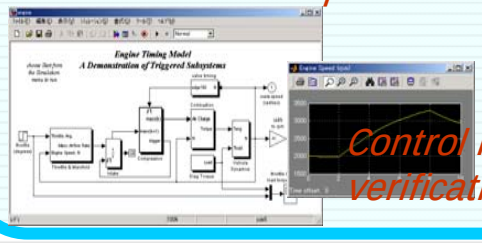


Contents

Model-based development

Specification development & Verification

Control model description tool

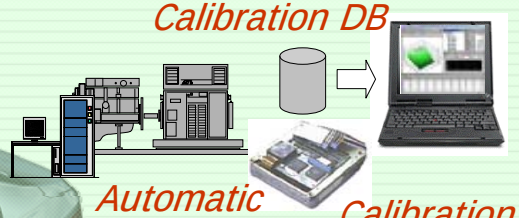


Control model verification tool

- Describe control spec in model
- Verify the spec by simulation

Calibration & Validation

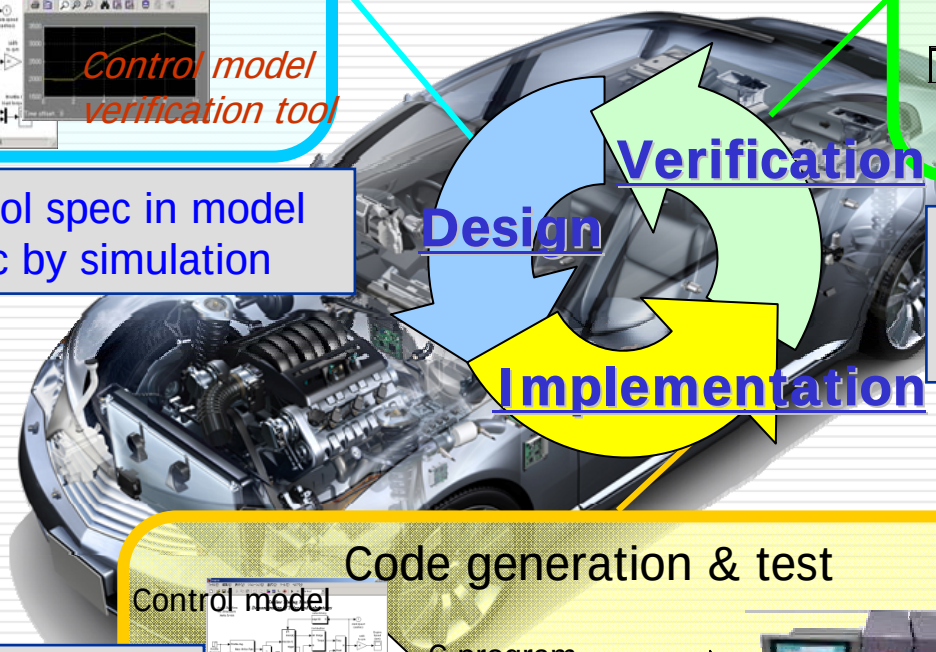
Calibration DB



Automatic calibrator

Calibration tool

- Calibration and validation using code, models, and hardware (incl. real vehicle)



Code generation & test

Control model

C program

Automatic code generation tool

Automated test bench

- Direct code generation from spec models
- Test comparing the code and the spec models

Issue: For consistent process, how to deal with the gap between control model and implement model

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Contents

Platform based development

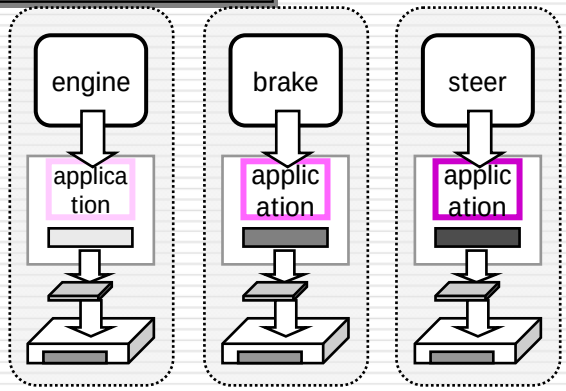
Technical trends

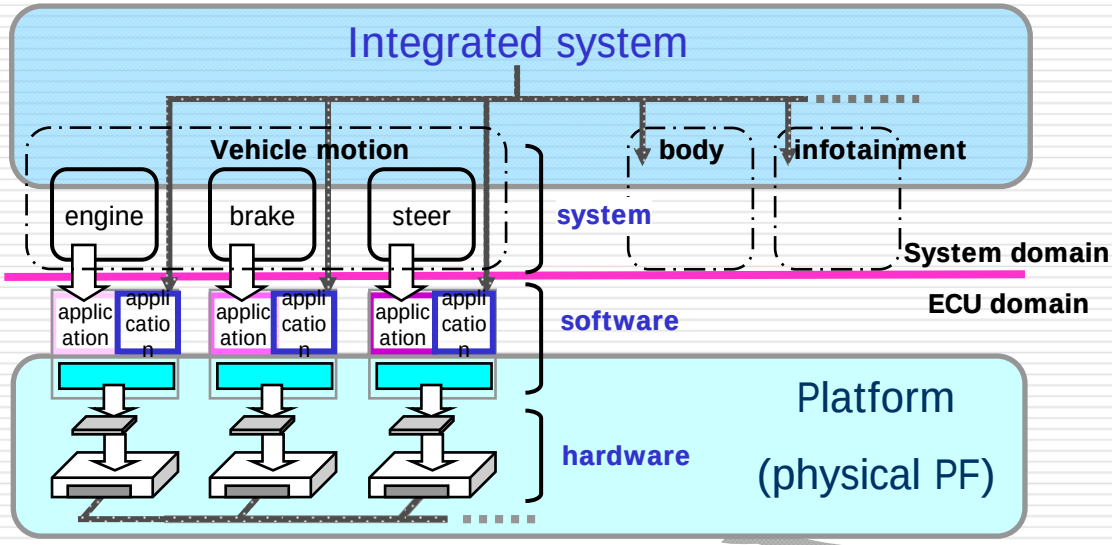
Platform based development is accelerating in the world.

The purpose of the platform based development

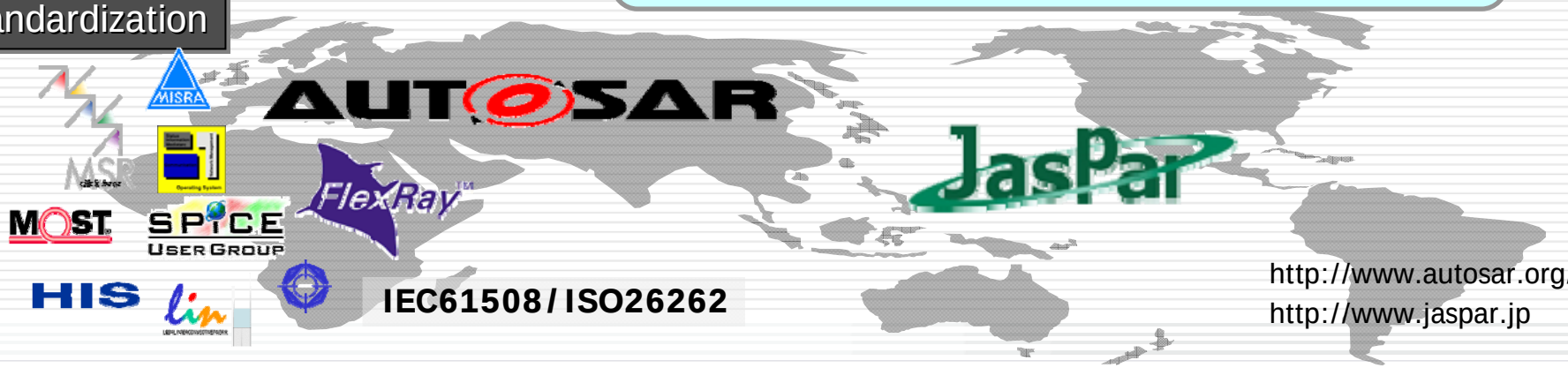
- Improve the value of systems and services across domains.
- Restructure business/technology model from vertical integration to horizontal work split.
- Secure quality of complicated vehicle control system.

Goal





Standardization



http://www.autosar.org/
http://www.jaspar.jp

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Architecture ～Functional vs Physical～

Example :
Advanced safety

Outside recognition: Other vehicles | White lines | Pedestrians | All directional

Vehicle motion: Distance keeping | Lane keeping | CAS | Skill support | brake assist | Parking assist | Autonomous travel | Auto-drive

Information: Road-vehicle comm. | Vehicle-vehicle Comm. | Satellite Comm. | Face direction (eye) | Alcohol | Disaster info.

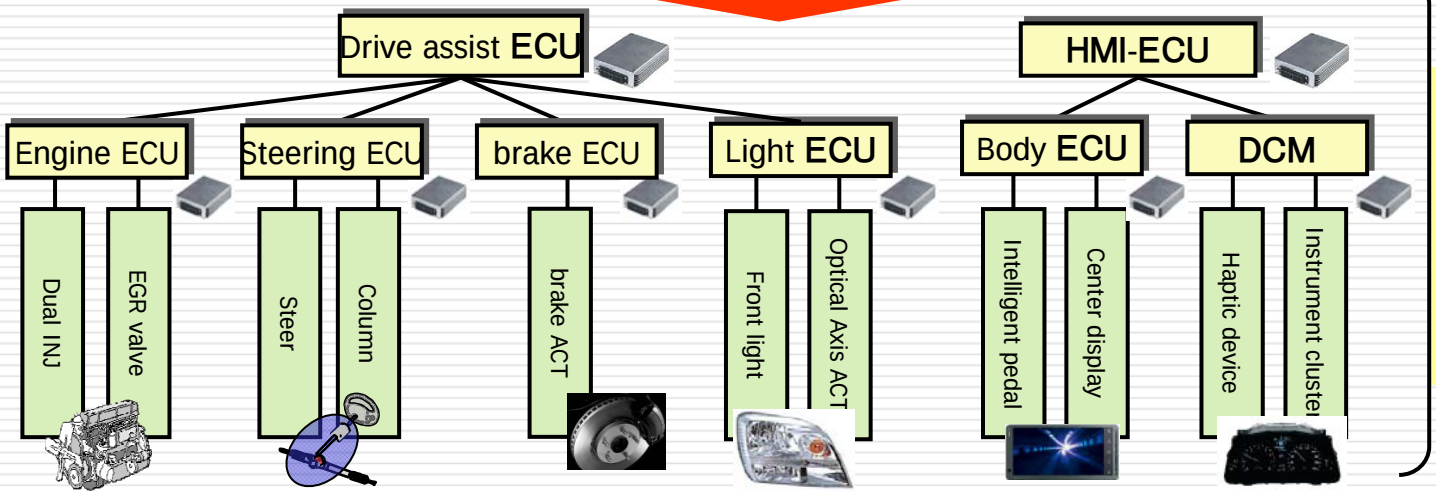
HMI: Emphasized display | Awakening | Driving instruction

Go | Turn | Stop | Visibility | Driver status

Functional world

Universal functional structure,

interfaces between functionalities



Physical world

Optimize QCD according to vehicle requirements.

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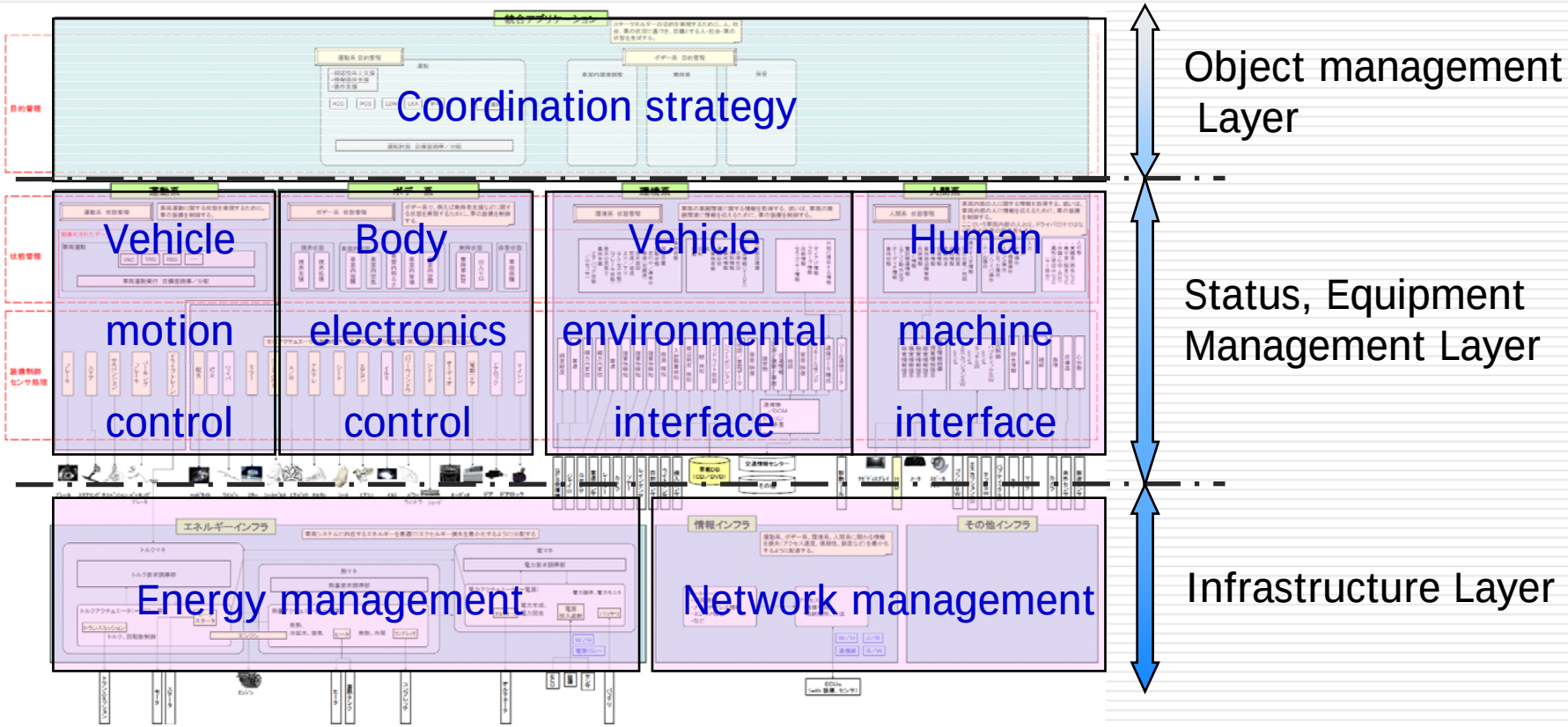
Functional architecture

Group control strategies by functional similarity view, for easy control system design



Grouping the structures, for further development efficiency:
Object, Status, Equipment(4 clusters) and Infrastructure(2 clusters)

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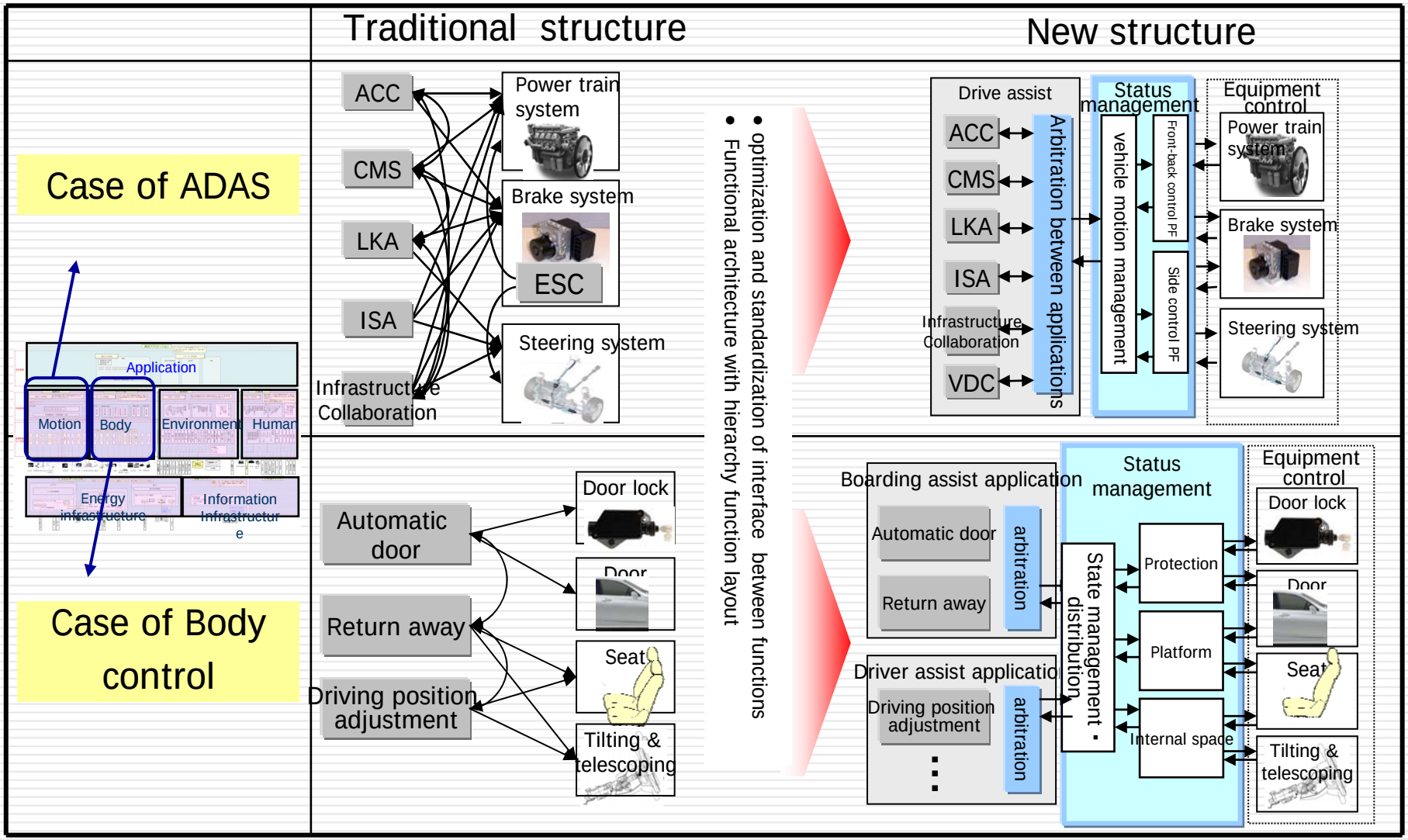
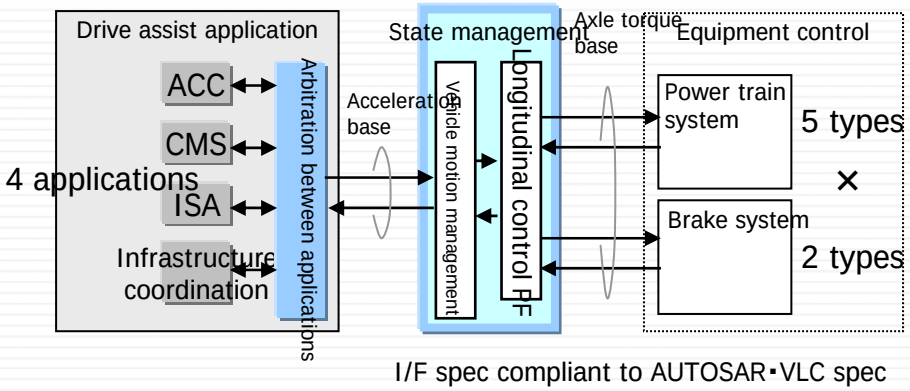
Application of functional architecture



Application of functional architecture ～Verification of effect～

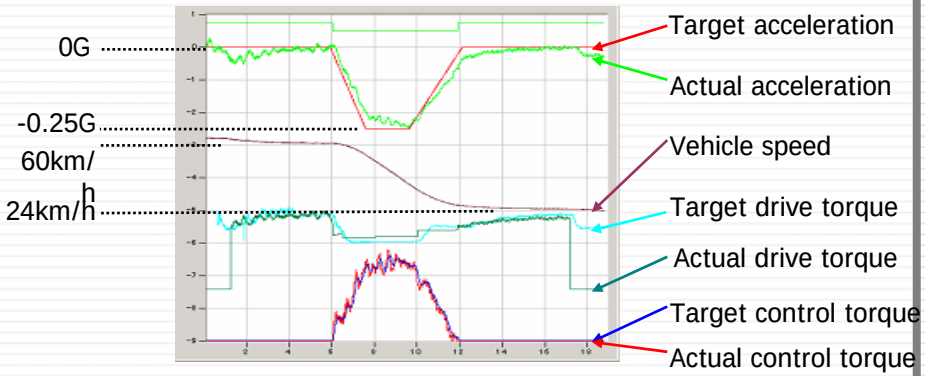
Drive assist system

- Implement ”Status management“layer between application vehicle motion system



I/F spec compliant to AUTOSAR・VLC spec

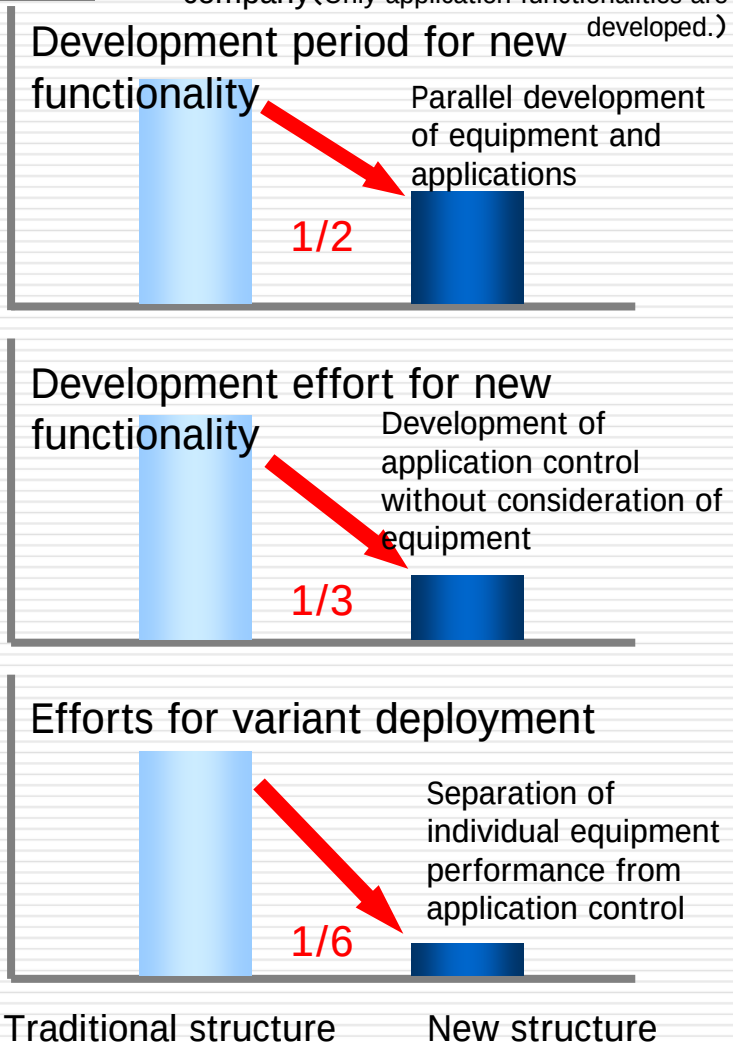
- Actual control data(Ex:60km/h⇒24km/h, 0.25G deceleration)



Application can be developed without consideration of vehicle motion system.

Effect

Verification results for the development of drive assist application within the company(Only application functionalities are developed.)



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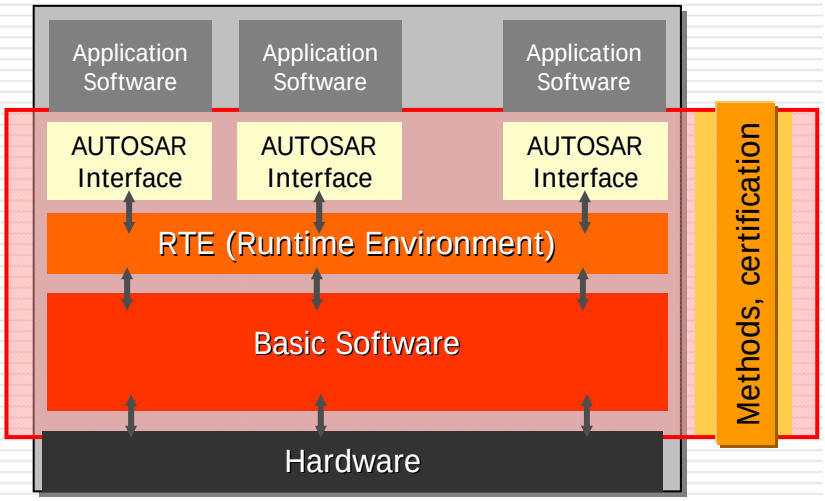
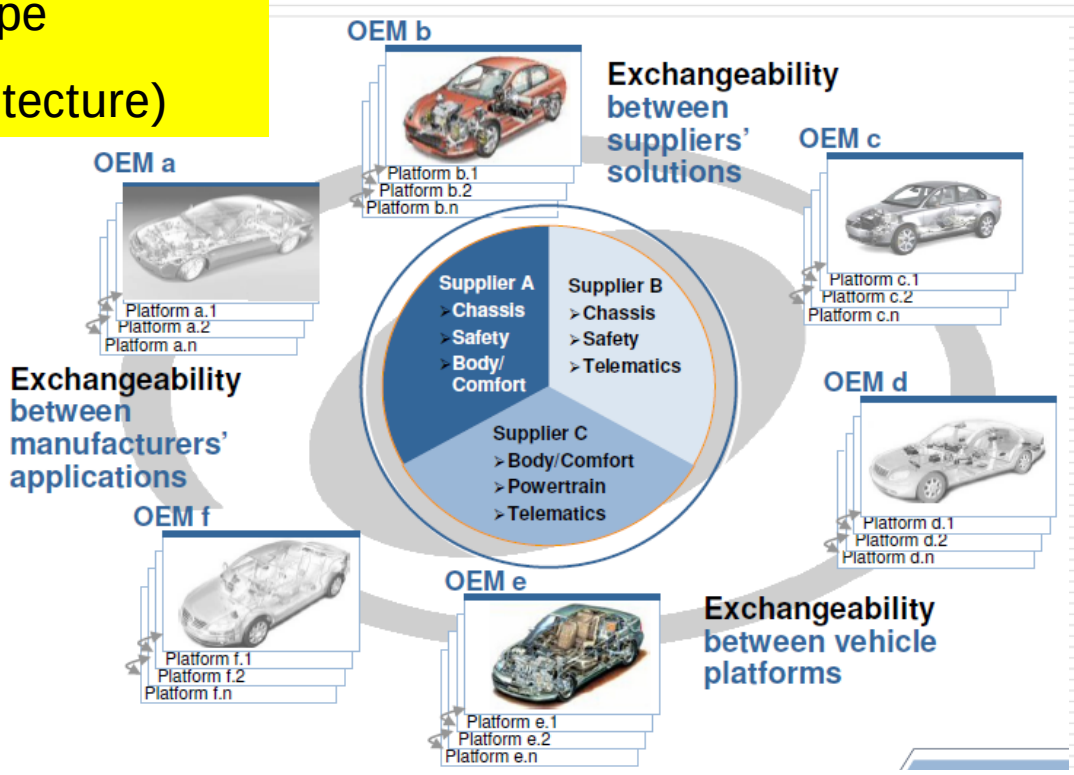
Standardization - Overview of AUTOSAR -

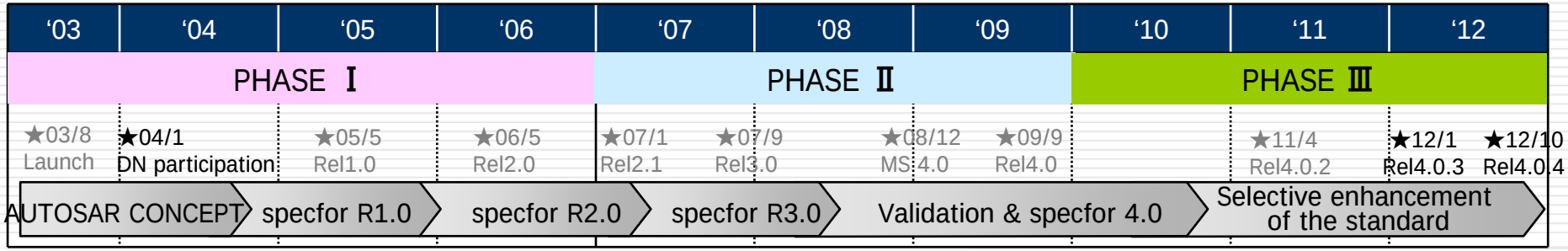
http://www.autosar.org/

Software standardization led by Europe

(The AUTomotive Open System Architecture)







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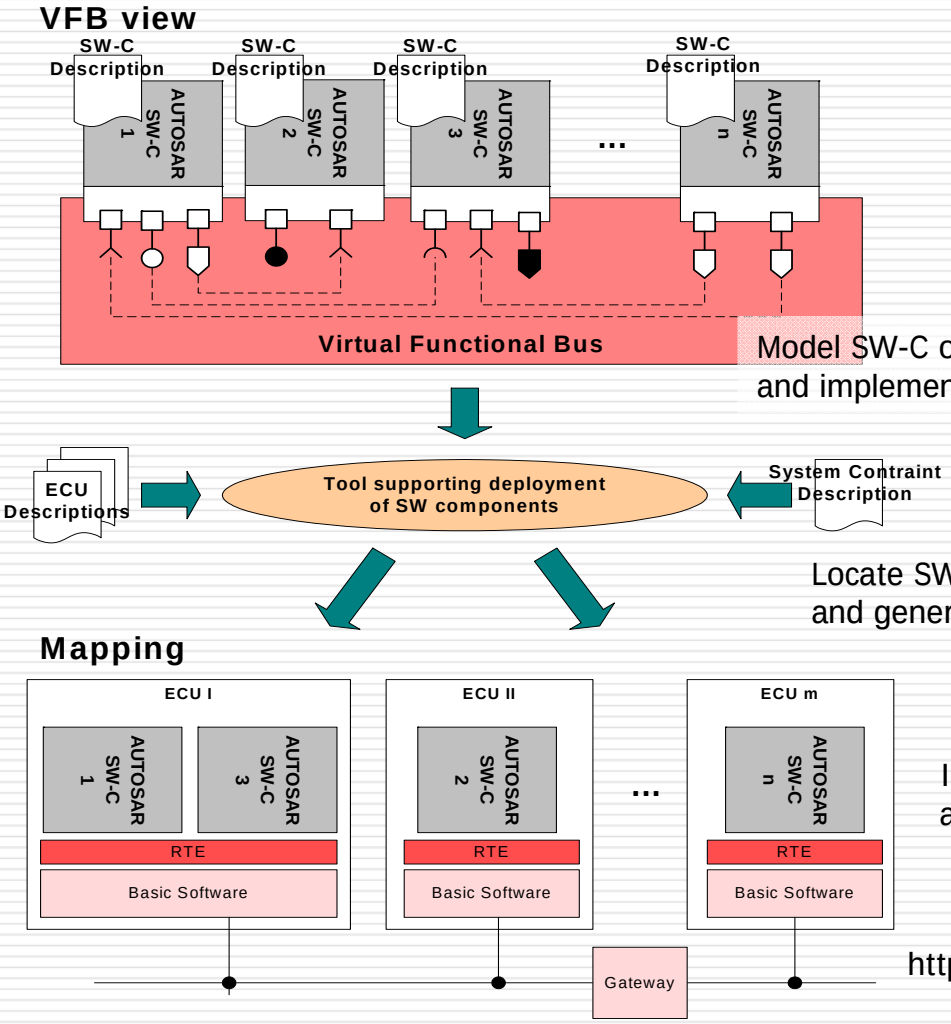
AUTOSAR Concept



VFB(Virtual Functional Bus)

Virtualization of hardware and network

- Development by combining components (SW-C) from multiple suppliers on VFB.
- Develop and manage a vehicle system consisting of multiple ECUs as one virtual ECU.

Integrate SW-C, RTE, Basic Software and make up ECU software

http://www.autosar.org/

Issue: Practical solutions for realization of the concept (Resource optimization, application design, tools etc.)

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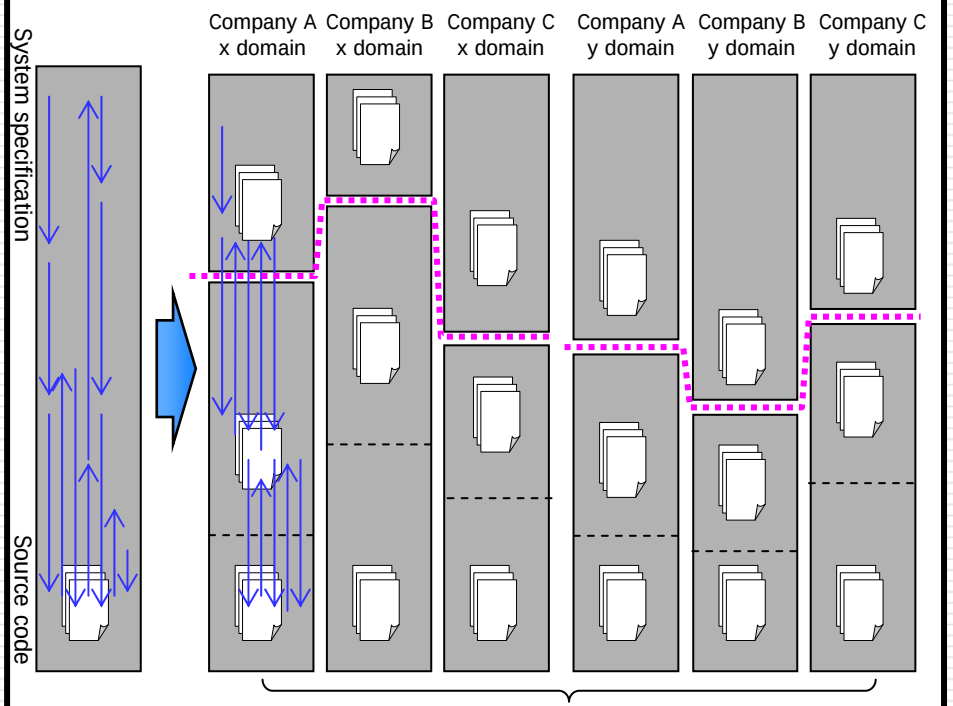
Significance of Platform base development

- Traditionally, the coordination/fine-tuned development approach demonstrated the strength of Japanese automotive industry
- In the future, creation of new values. including the viewpoints of total optimization and industrial collaboration, will become the core of competitiveness

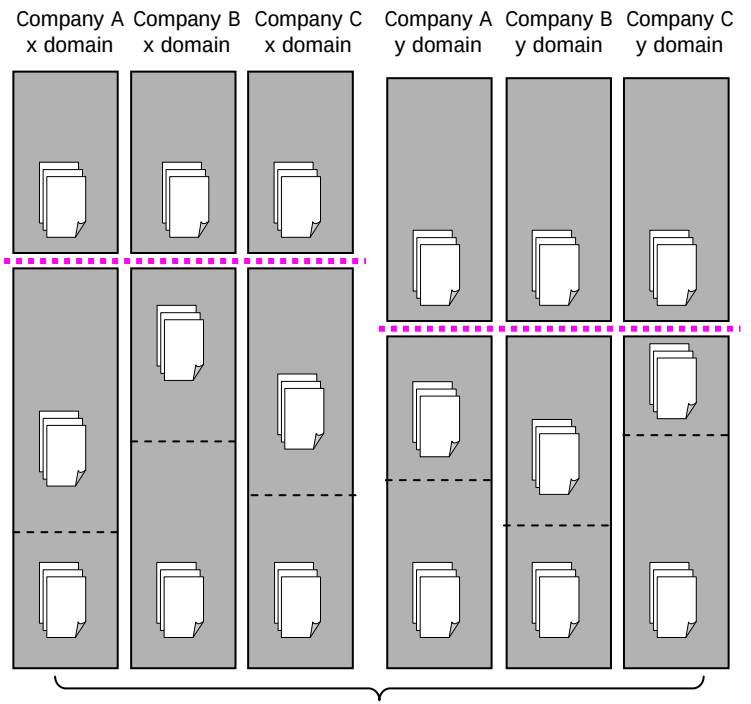
Actual integral development style



After integral, documents are only source code . . .

Architecture and I/F are fragmented, OEM / Supplier / Domain

Future integral development style



Define architecture and I/F optimized for each domain

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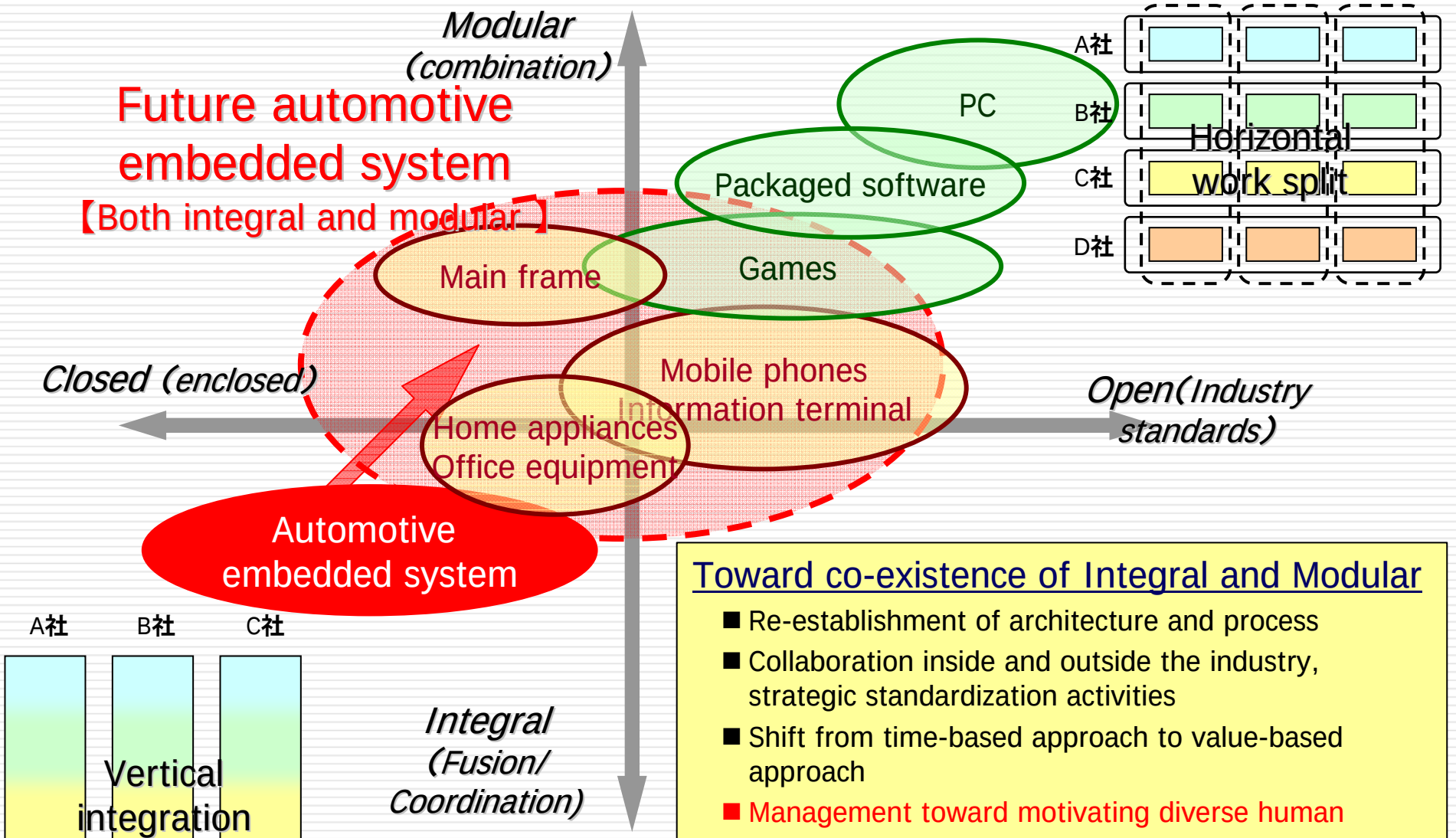
Direction and challenges for the future



Toward co-existence of Integral and Modular

- Re-establishment of architecture and process
- Collaboration inside and outside the industry, strategic standardization activities
- Shift from time-based approach to value-based approach
- Management toward motivating diverse human resources

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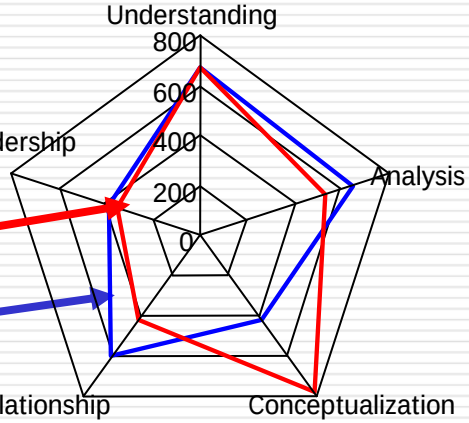
Management of diverse human resources

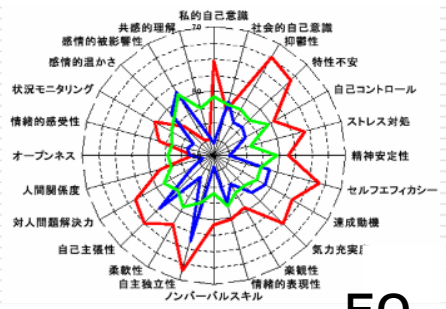
Areas

Phase

	Planning・Resea	Development	Mass production
System	Sow seeds	Develop Standard assets	Generate profits by producing products
Software			
Support	Process impr		agement・Human development・ Intellectual property management

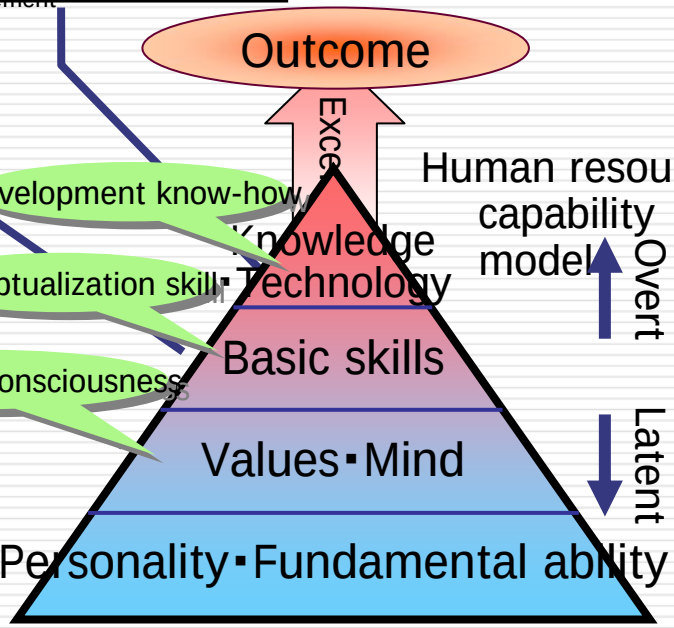


■ Utilizing latent talent measurement indicator for training and management



EQ

Harman model



Clarify “What an employee wants to do”, “What an employee can do”, and globally implement “right person in a right place”

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Contents

Summary

- Global scale social contribution is required for automotive industry.
  - Global environment：Promotion of electric driven systems for reduction of CO2 emission.
  - Traffic accidents：Development of advanced safety equipment toward a zero-accident society.
  - Future society：Realization of connected automobiles in the ubiquitous society.
- DENSO will continue the challenge of changes/reform of automotive embedded software development.
  - Architecture and process to realize both product enhancement and QCD.
  - Platform-based development to facilitate the change from vertical integration to horizontal work split.
  - Strategic standardization activities to promote total optimization.
  - Management system to motivate diverse human resources.
- To establish a foundation which supports not only our company but also the automotive industry, DENSO would like to actively promote activities in cooperation with the companies and individuals in other fields.

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Thank you!

Your attention has been appreciated

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