X-by-Wire Systems

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Hitachi, Ltd.

1. What's X-by-Wire ?

2. Our Approach

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2. Our Approach

What's X-by-Wire ?

"Fly-by-Wire" for Automobile

Also called as Drive-by-Wire

1998:
Munich

FTCS -28

- Safety-Related Fault-Tolerant Systems in Vehicles (X- By-Wire)
- User Congress on Dependability of Automotive Systems

"Probability of success is 3%. So they are making efforts"
– Hr. Ernst Schmitter, Siemens AG

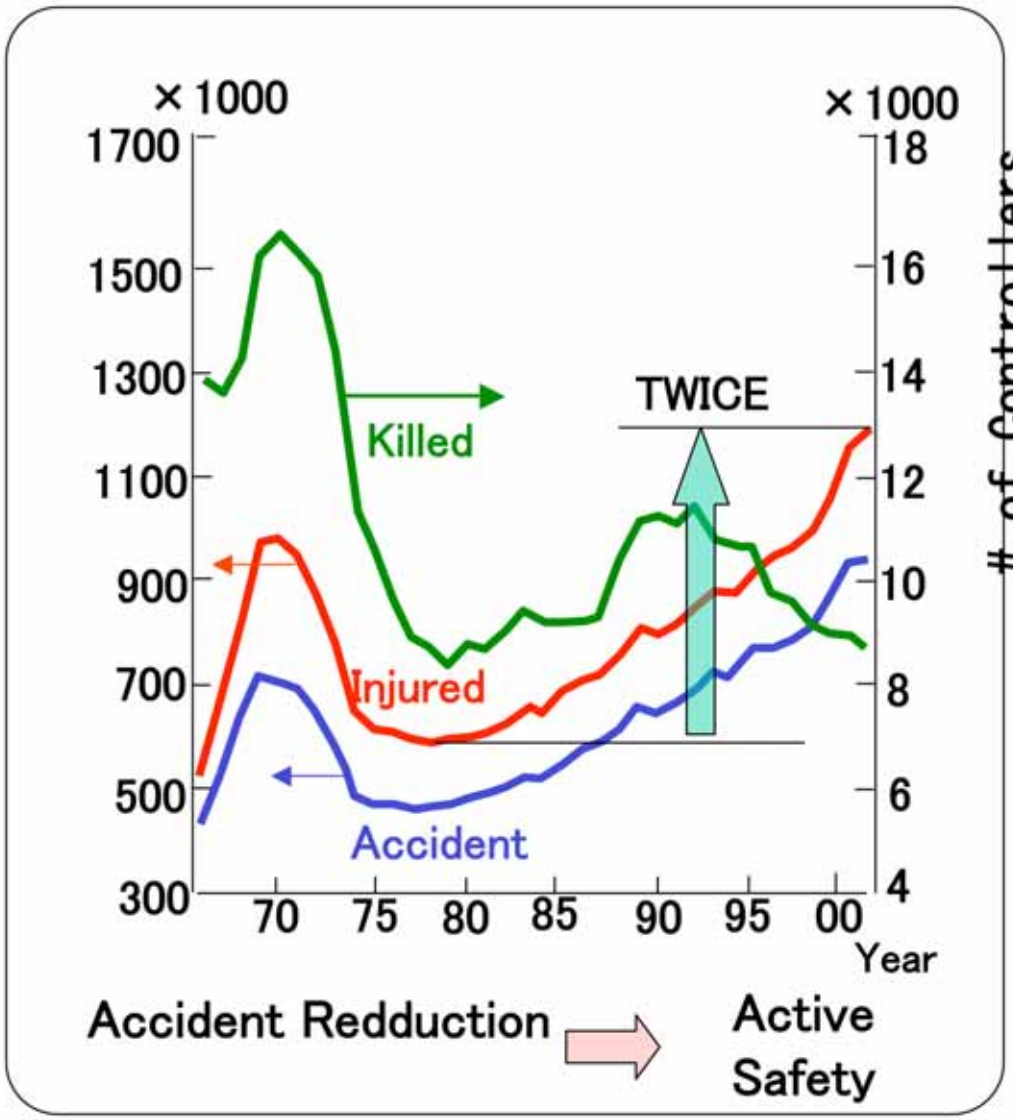
2004:
Detroit

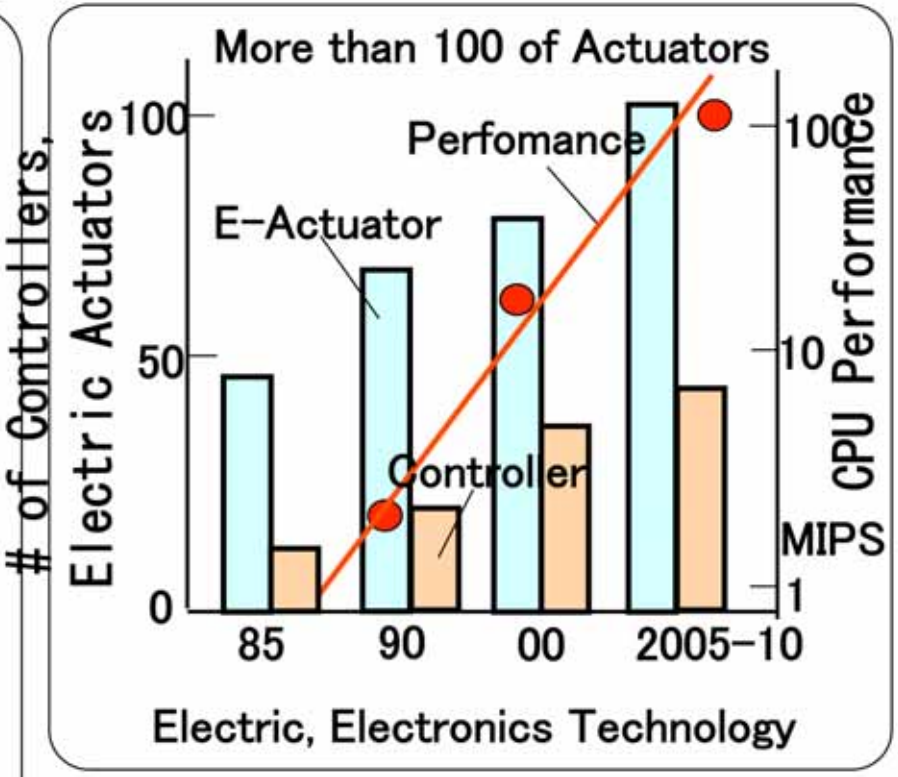
SAE (Society of Automotive Engineers) 2004

- Distributed Embedded Systems Engineering (4 sessions)
- In-Vehicle Networks (3 sessions)

Sorry for absence from Tahiti

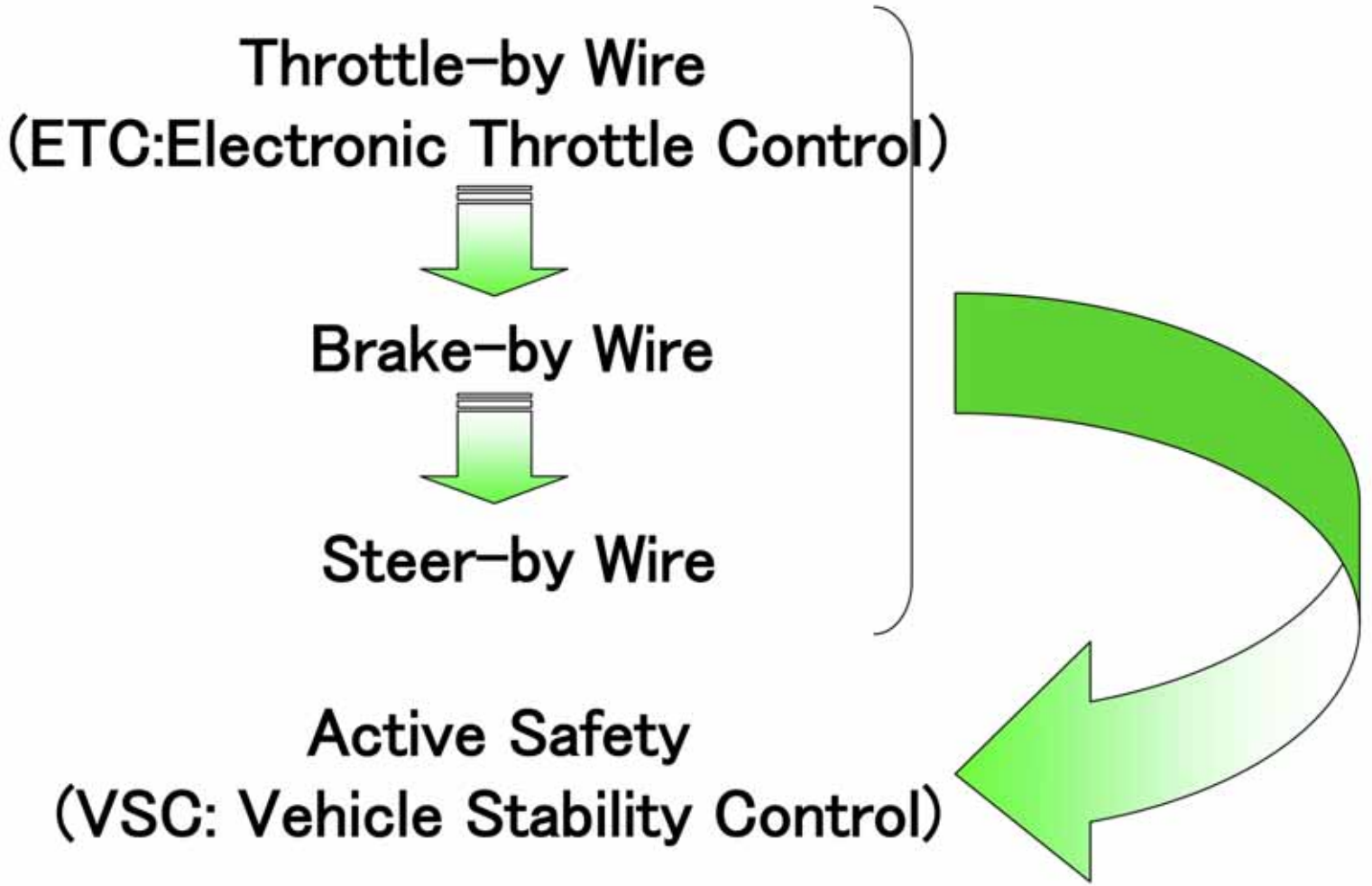
Necessity for Active Safety



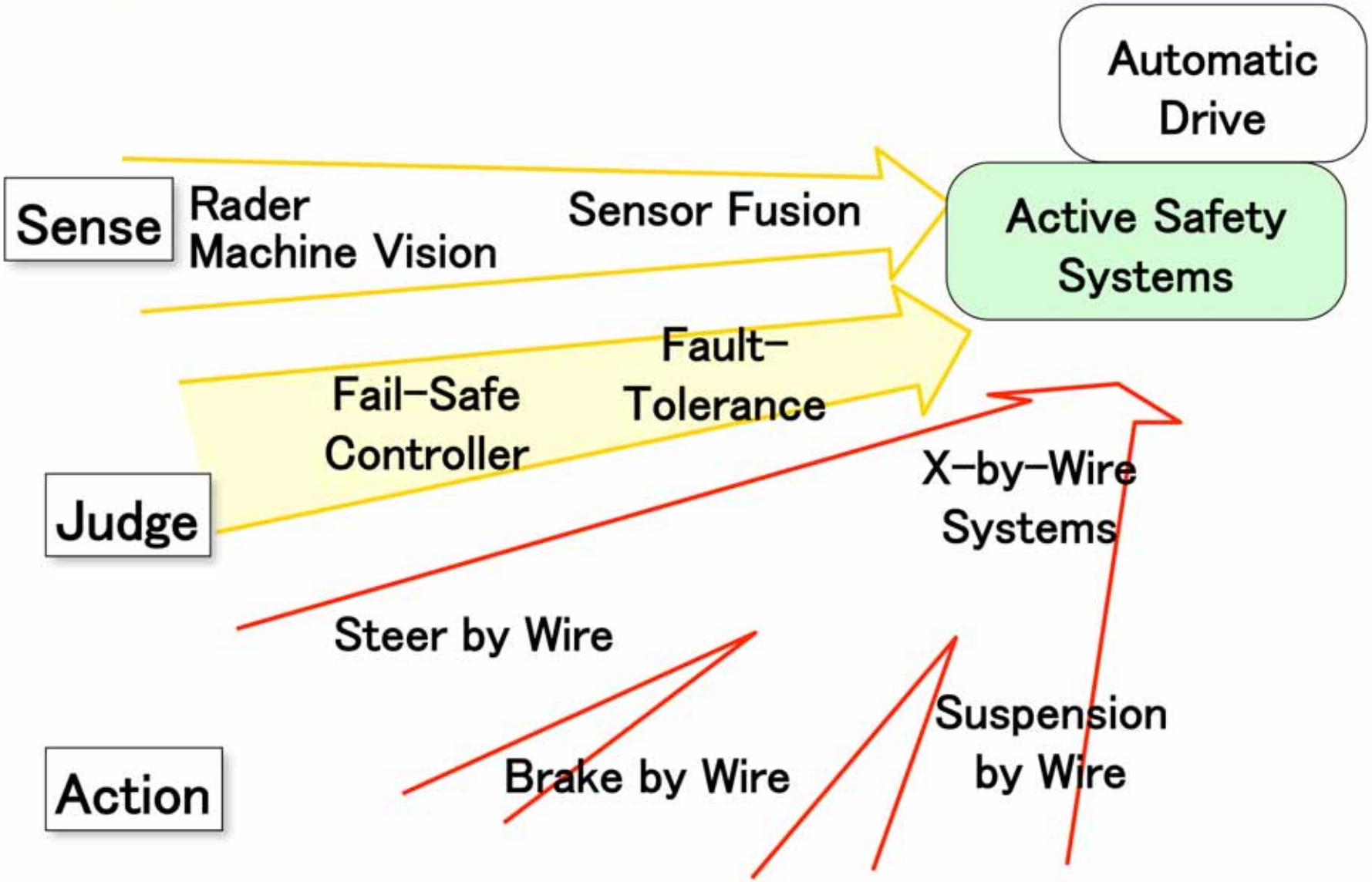


Active Safety by Electric /Electronic Technology

X-by-Wire Road Map



X-By-Wire Road Map



Concept Cars

Daimler Chrysler <R129> 1997

X-by-Wire Operated with a Side Stick

Side Stick

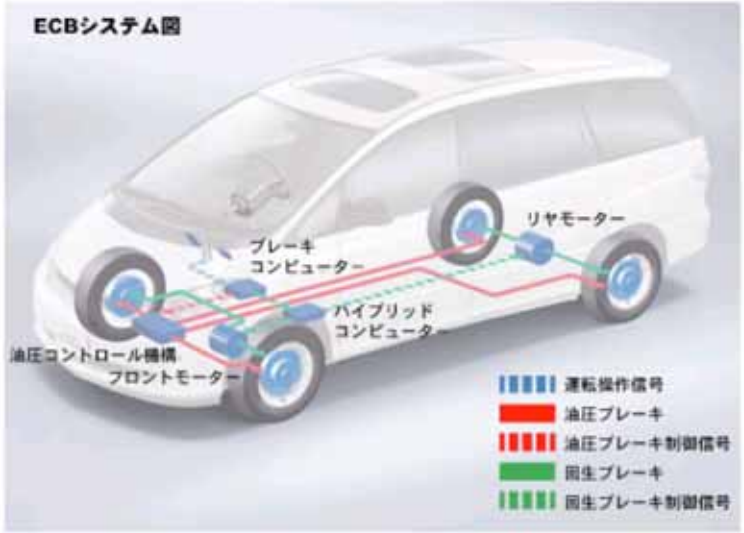
GM <Hy-Wire> 2002 : Fuel Cell Vehicle

Power-train Platform with 11” Thickness. Layout-Free Cabin

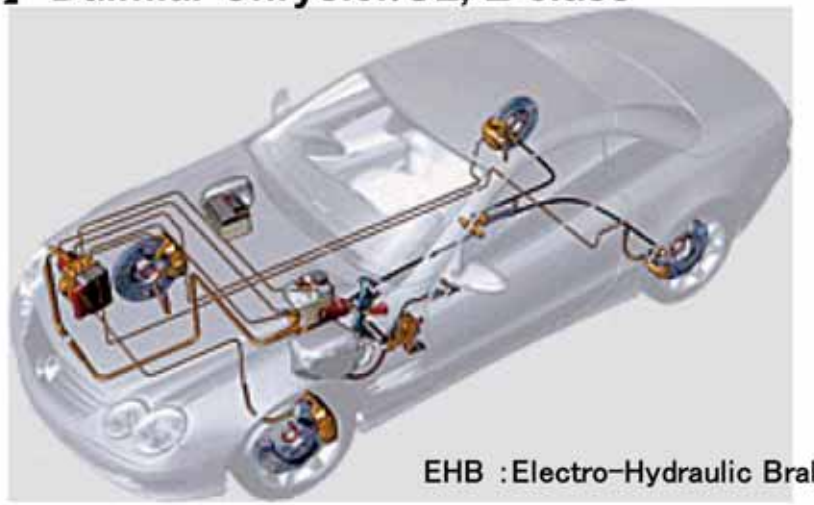
X-by-Wire Real Cars

Brake-by-Wire

【EHB】 Toyota／Estima-Hybrid



【EHB】 Daimlar Chrysler/SL, E-class



EHB :Electro-Hydraulic Brake

Steer-by-Wire

【Variable Gear Ratio】 Honda/S8000

【 Variable Gear Ratio 】 Toyota/Land Cruiser

Effects of X-By-Wire

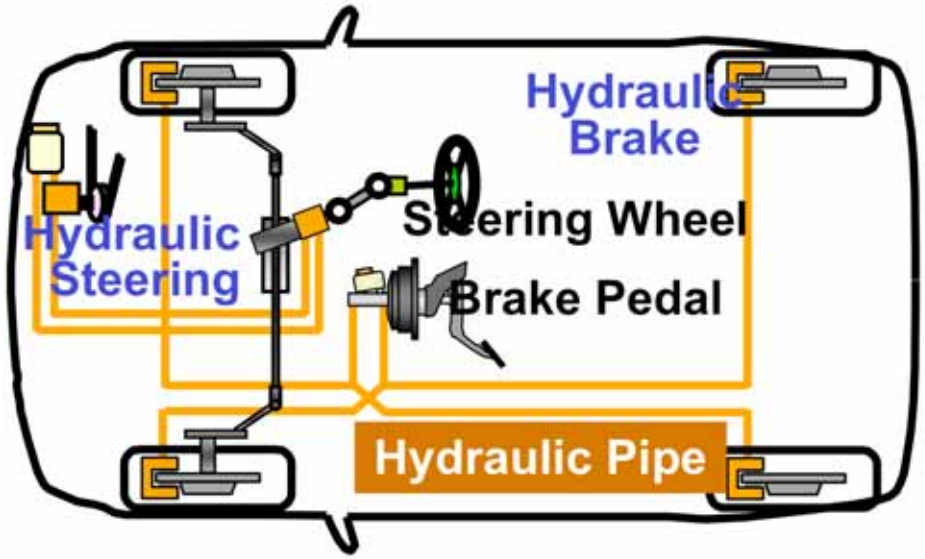
With X-By-Wire, Cars become…

Low Emission, Human Centered

Architecture	Free Layout
For Environment	Energy Saving Regenerative Brake Dry
Safety	Drivability

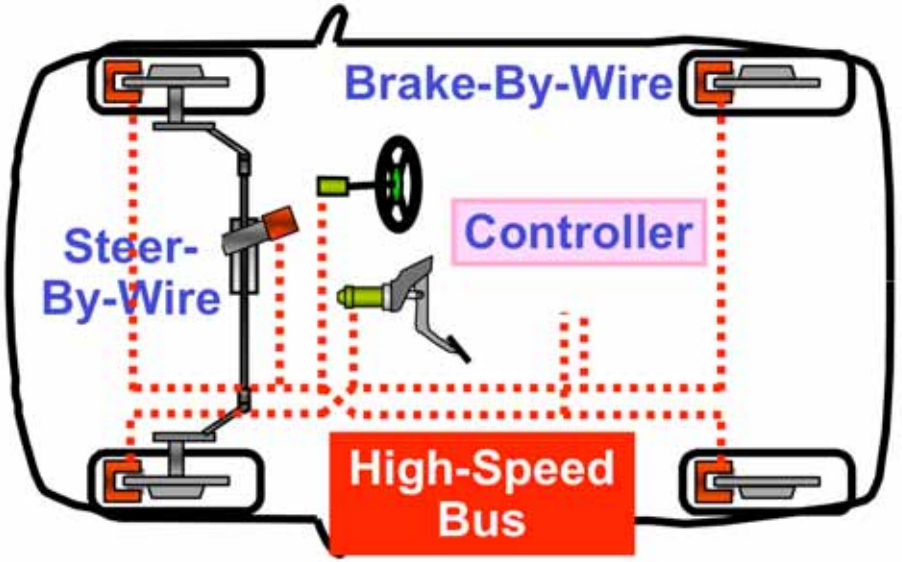
X-By-WireSystem

Conventional



Mechanically Connected among Actuators and Mechanics

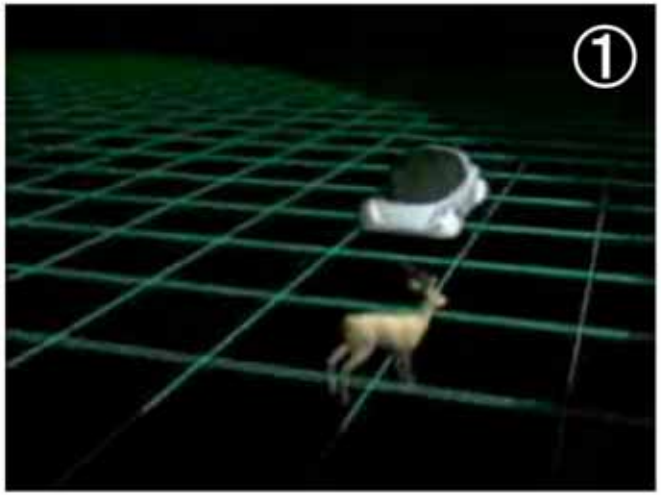
X-By-Wire System

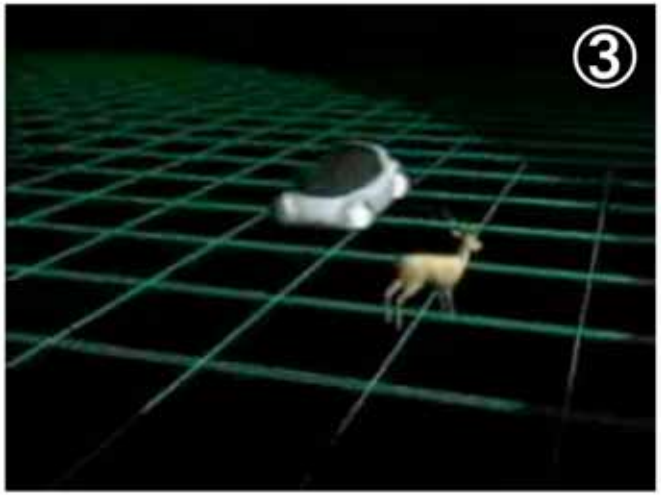


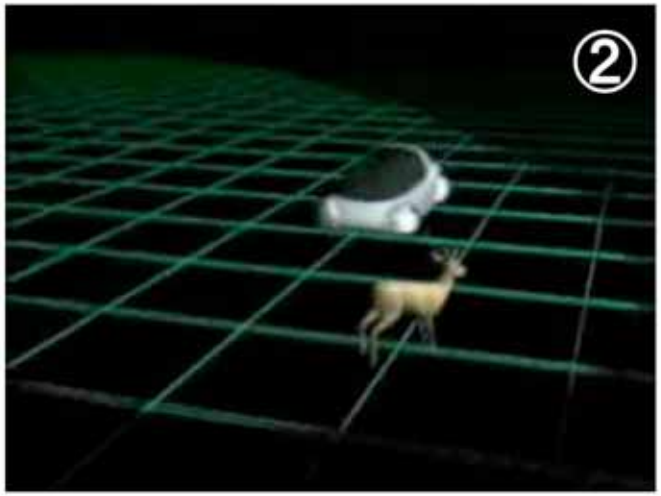
Integrated Control Connecting Components via High-Speed Bus

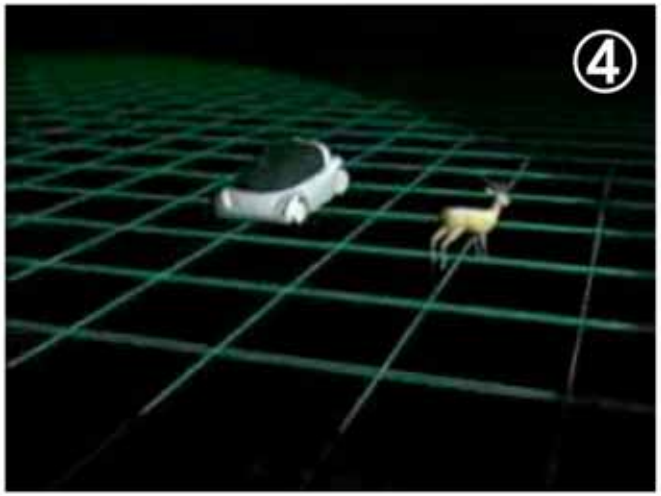
Hitachi's Concept Car

From Promotion Video at Tokyo Motor Show, 2003









Inexpensive Dependability

"Aero-space is no longer high-tech.:
Reliability can be improved with cost.
X-By-Wire is the high-tech., which realizes
dependability with low-cost."

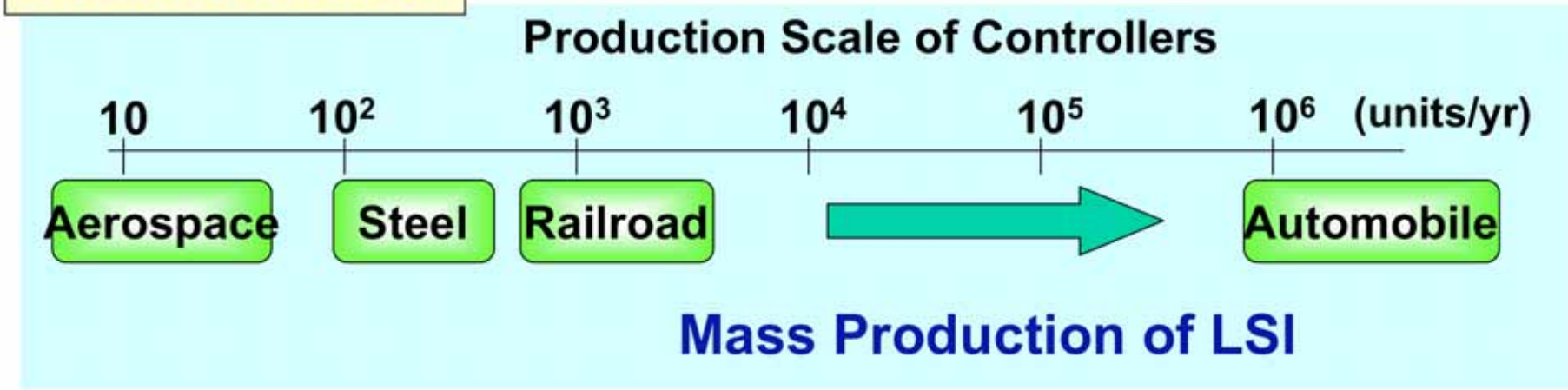
- Prof. M. Broy, Technical University of Munich (FTCS-28)

1. What's X-by-Wire ?

2. Our Approach

Low-Cost Dependable Technology

Cost Reduction



Low-Cost Dependability with LSI Technology

- ✓ Redundant CPUs in One Chip
- ✓ Self-Checking / Failsafe Technology
- ✓ Optimal Clock Diversity

and Autonomous Decentralized Concept

Our Expertise in Dependability

1960 1980 1990 2000

Nuclear Power Plants

Autonomous Decentralized Systems

Space Computer

Steel Manufacturing

Gotemba, 1988

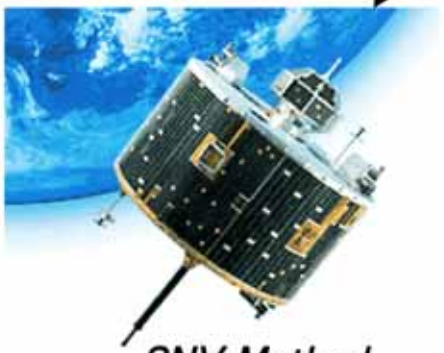
FT-Online Transaction Processor

FT6100 3500/FT

Fly-by-Wire
Fail-Safe Controller

X-by-Wire

Train Control Systems



SNV Method

Hiten, Nozomi Onboard Computer

ATC

Appi, 1996

Electric Railroad Crossing Controller

Hakone, 2005

ATOS

SNV: Stepwise Negotiating Voting, ATC: Automatic Train Controller,
FTC: Fault-Tolerant Computer
ATOS: Autonomous Decentralized Transport Control System

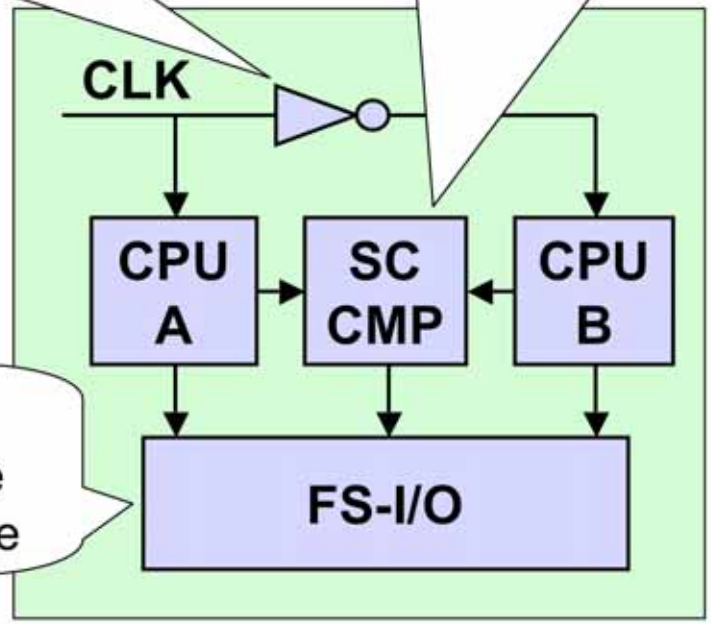
Making Controllers Dependable : Dual CPUs

Dual CPU Controller

Compares outputs of two CPUs.
Takes fail-safe mode operation, if there is a difference.

Optimal Clock Diversity
- Operates CPUs out-of-phase
- Improves noise immunity

Self-Checking Comparator
- Self-checks its own operation
- Compares output of two CPUs



Fail-Safe I/O
- Executes fail-safe mode operation on CPU failure

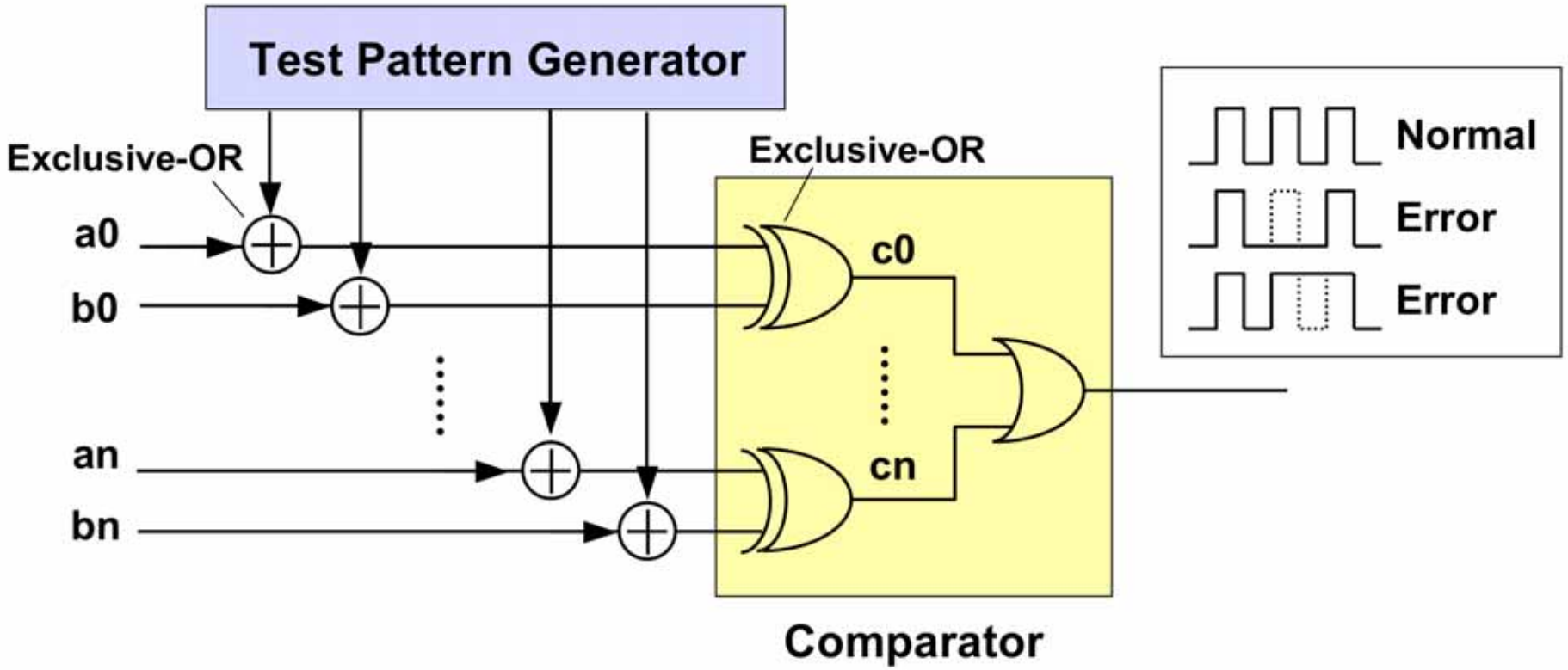
Applications
- **Digital ATC**
- **Crossing Controller**

Self-Checking Comparator

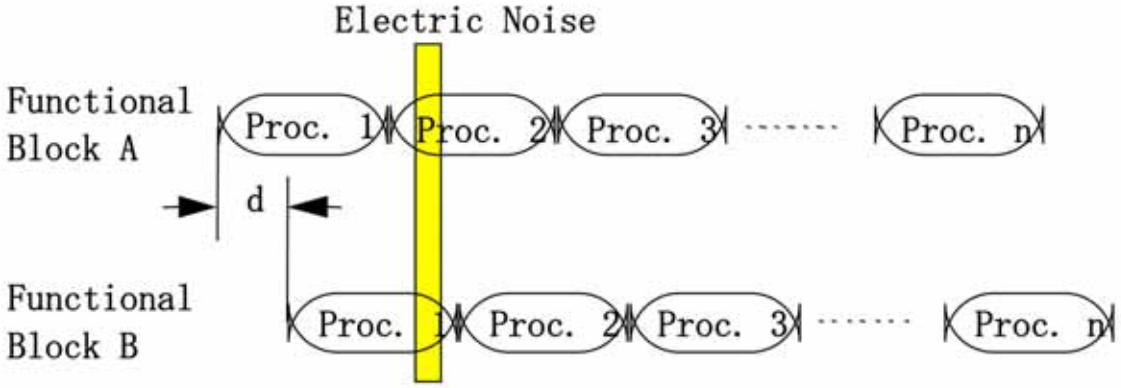
Comparison of two outputs

CPU A	a0	a1	a2					an
CPU B	b0	b1	b2					bn

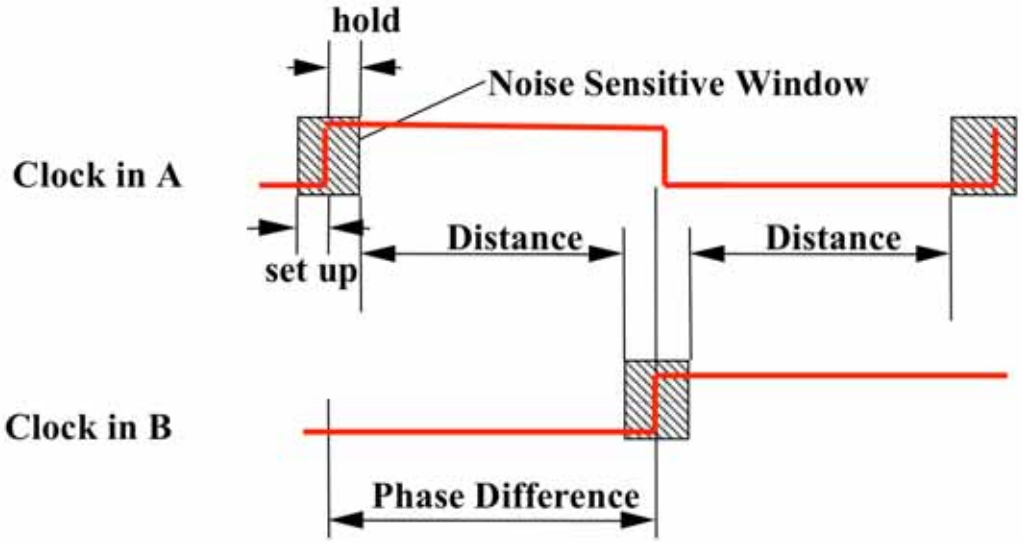
Test Pattern Generator
inputs cyclic error signals intentionally



Effects of Time Diversity

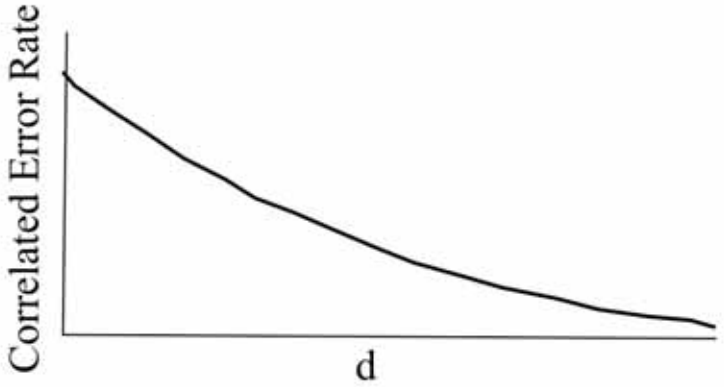


Macro Effect



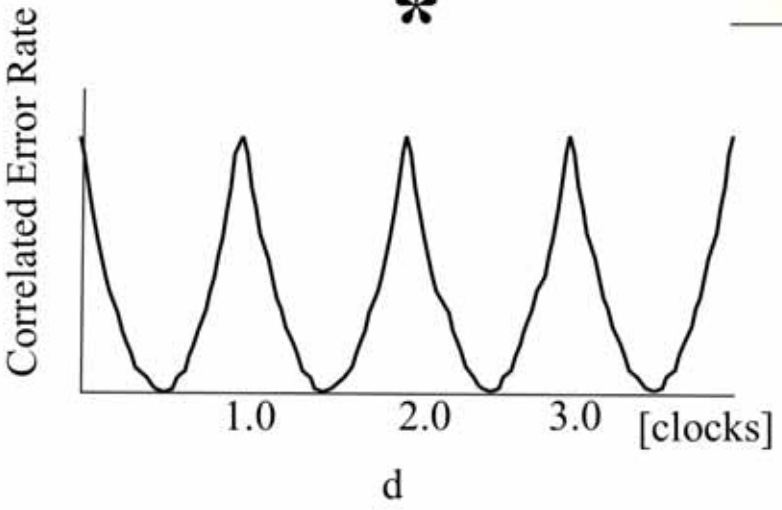
Micro Effect

Effects of Time Diversity

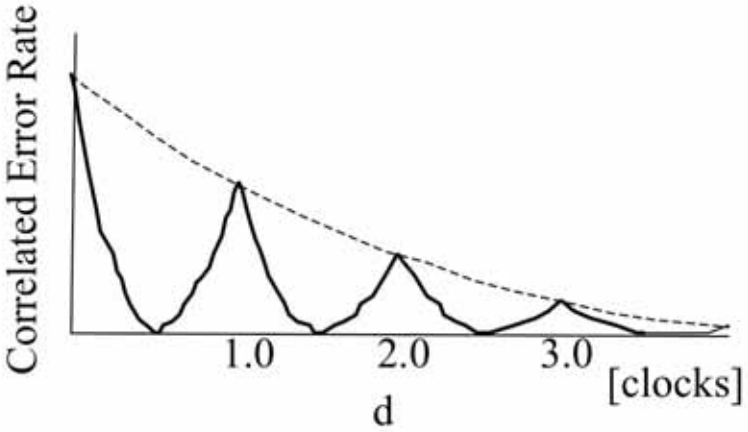


(a) Macro Effect

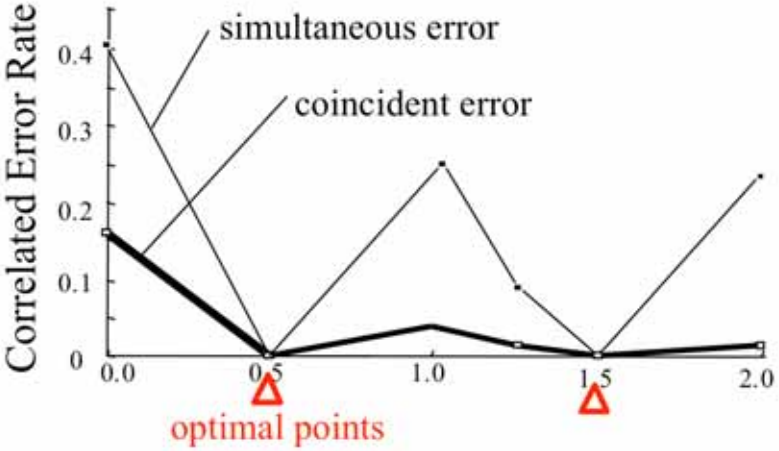
*



(b) Micro Effect

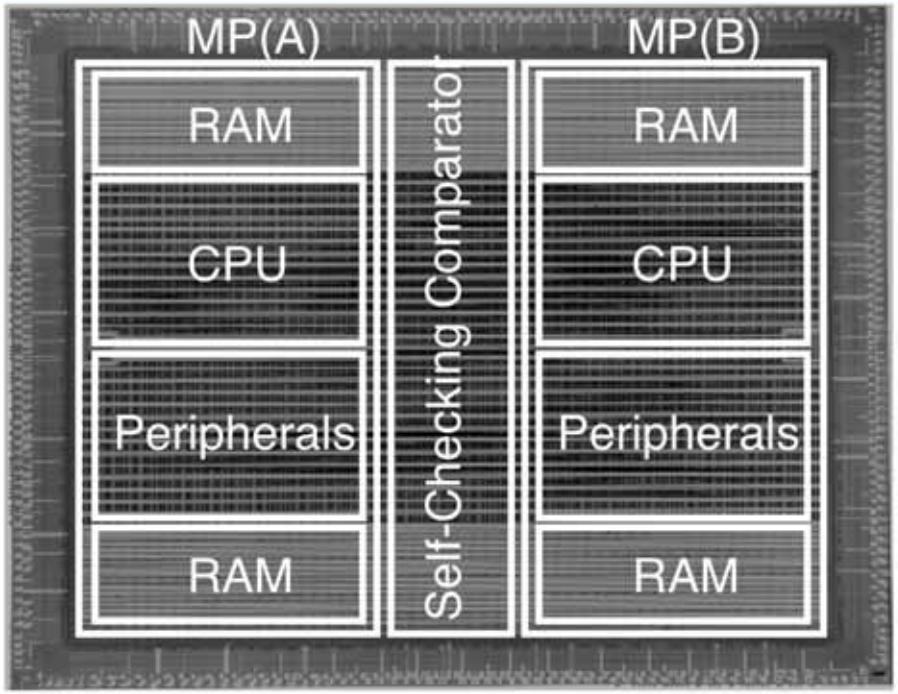


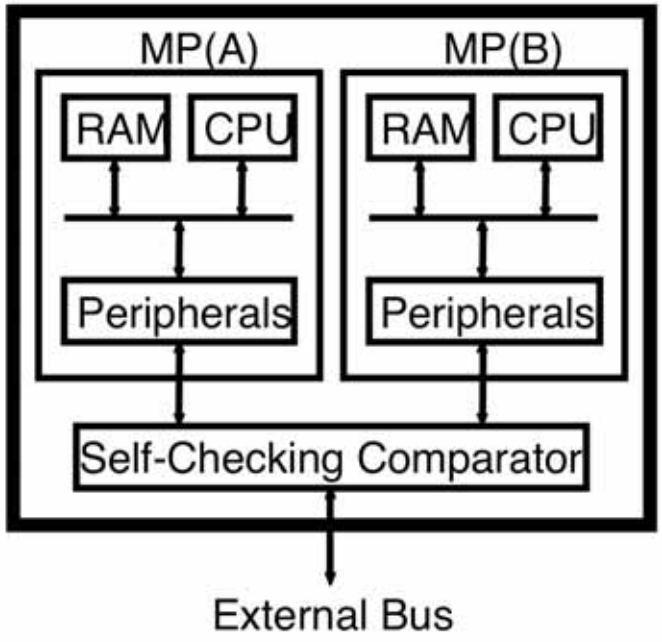
(c) Overall Effect



Experimental Results

Intra-Chip Redundancy CPU (FUJINE)

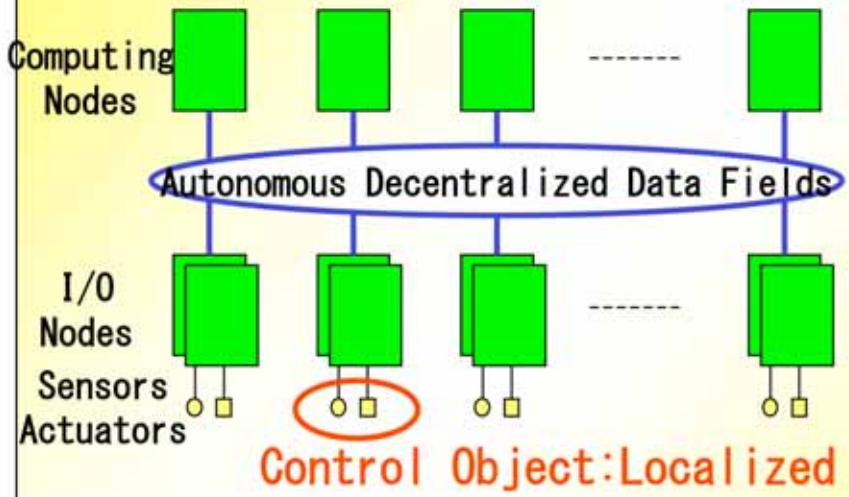




Process	0.35 µm 5 Metal CMOS
Hard Macros	PLL x 2, RAM(40KB)
Random Logic	740k gates
Chip Size	14.75 mm□
Operating Frequency	60 MHz
Power Dissipation	2.6W @ 60MHz
Package	479pin BGA

Autonomous Decentralized Systems

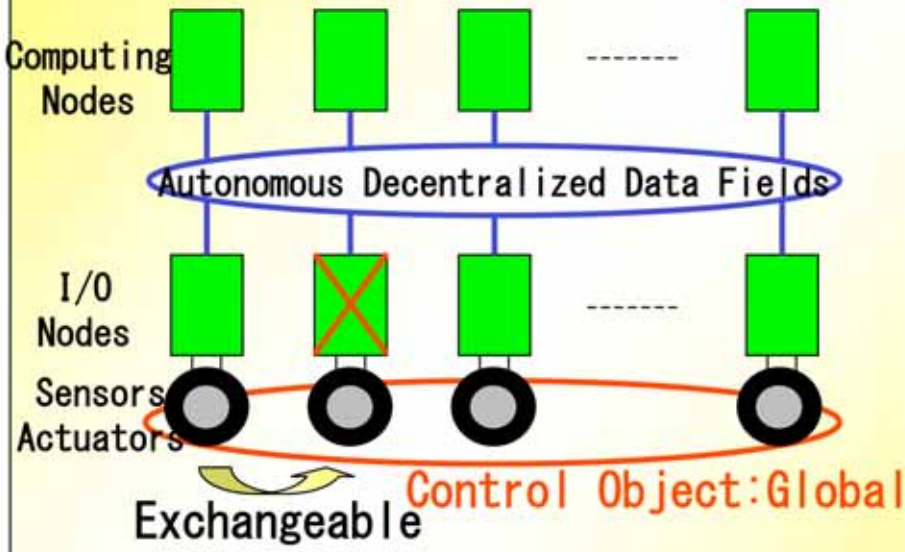
For Most of Applications



Merits;
- ✓ Online System-Expansion
- ✓ Computing Node Dependability

(I/O nodes should be redundant)

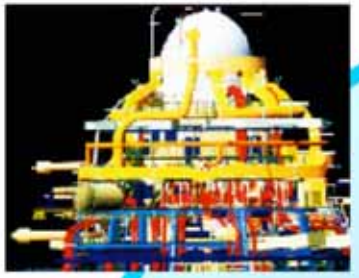
For Automotive/Aerospace



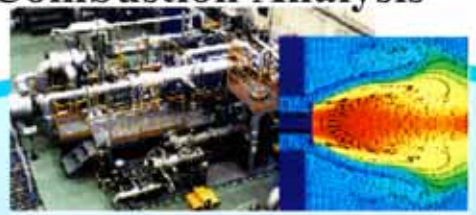
Merits;
- ✓ Online System-Expansion
- ✓ Computing Node Dependability
- ✓ I/O Node Dependability w/o Redundancy

Hitachi's R&D on Automotive Systems

Nuclear Reactor
-Hydraulic Dynamics Sim.



Gas Turbine
Combustion Analysis



Power IC

Automotive Systems

Environment
Low Emission

Safety
Drivability

Target

Information
Service

Motors, Generators

RISC
Processors

Train Control

Car Navigation

References

(on recent research works only)

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[9] Nobuyasu Kanekawa et al., Self-checking and Fail-safe LSIs by Intra-chip Redundancy **FTCS-26** (1996)

[10] Nobuyasu Kanekawa et al., Fault-Detection and Recovery Coverage Improvement by Optimal Time-Diversity, **FTCS-28** (1998)

[11] Kotaro Shimamura et al., Fail-Safe Microprocessor Using Dual Synthesizable Processor Cores, **The first IEEE Asia Pacific Conference on ASICs**, p.46-49 1999

[12] Kentaro Yoshimura et al., A Dependable and Cost-Effective Vehicle Control Architecture for X-By-Wire Systems Based on Autonomous Decentralized Concept, **DSN-2005** (2005)

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Inspire the Next