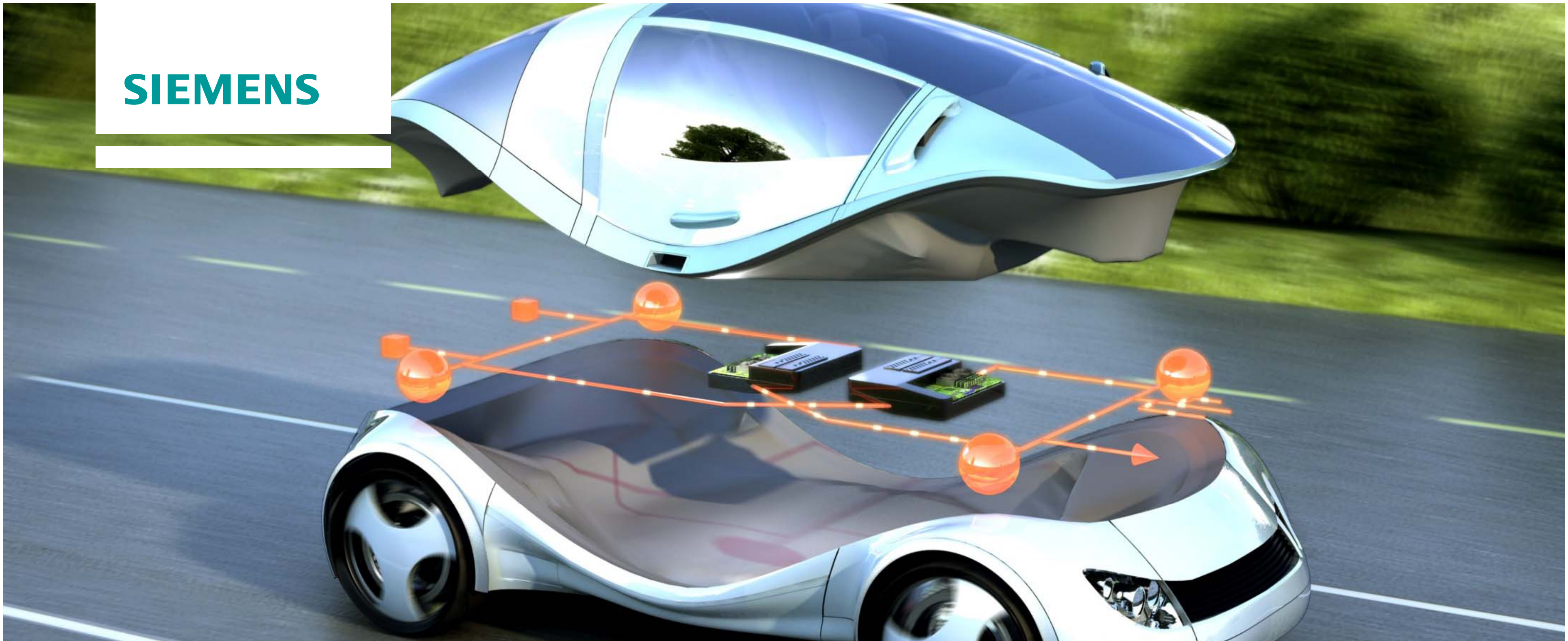

Cornel Klein | Siemens AG, Corporate Technology

# A Software- and Systems Platform for Smart Vehicles

**CLOSER, VEHITS and WEBIST 2015**
**Lisboa, 20/May/2015**

# Outline

- Research on Electromobility at Siemens CT
- Reasons for a radical change in automotive E/E architectures
- The RACE project
  - Architecture
  - Implementation
  - Demonstrators
- Related work
- Research outlook

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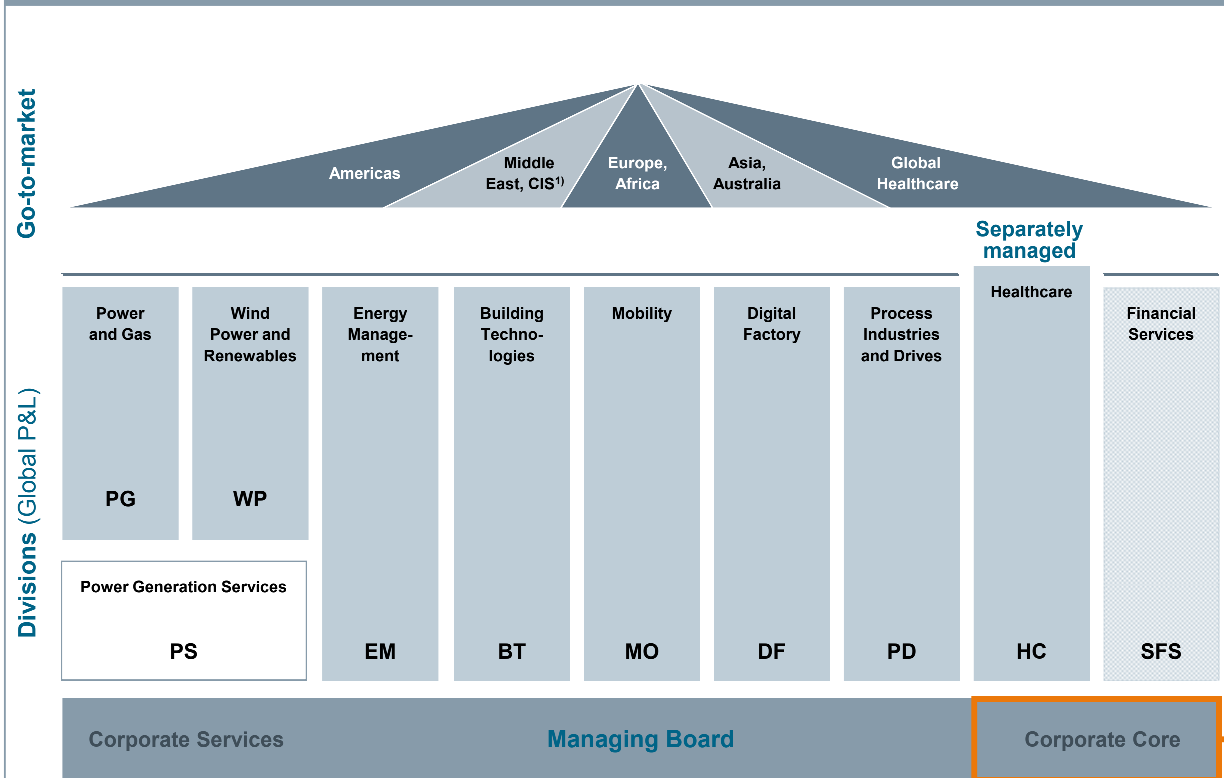
# “Corporate Technology“ is part of the Corporate Core

CT's missions

## Siemens organization




1) Commonwealth of Independent States

## 3 missions of CT

- Secure the **technological and innovation base** of Siemens
- Secure the **technological and innovation future** of Siemens
- Support Siemens as a **technology company**

# Corporate Technology contributes to making Siemens more competitive

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## CT Organization

**Corporate Technology (CT)**
**CTO: Klaus Helmrich**

**Technology and Innovation Management (TIM)**
- Develops the technology and innovation strategy and portfolio
- Develops cooperation with external partners

**New Technology Fields (NTF)**
- Focus on interdisciplinary long-term oriented research projects

**Research and Technology Center (RTC)**
- Delivers cutting edge research services to the Sectors and innovations for Siemens

**Intellectual Property (IP)**
- Delivers excellent IP services and drives the Siemens IP strategy

**Innovative Ventures (IV)**
- Builds the bridge from technology to business e.g. via technology commercialization

**Development Center (DC)**
- Provides high quality product development services from a nearshore and offshore base

**Process and Production Consulting (PPC)**
- Offers consulting services to optimize innovation, R&D, engineering, procurement, supply chain logistics, production, services, project and crisis management

**Corporate Standards and Guidance (CSG)**
- Setting Siemens standards for technology and processes in close collaboration with Sectors

**Corporate *top*⁺ & Quality Management (CT *top*⁺&QM)**
- Contributes to setting high quality standards and driving business excellence within Siemens

# CT "New Technology Fields" drives major innovation projects for Siemens

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CT New Technology Fields (NTF)

**Innovation management process**

| Innovation portfolio setting (CT TIM) | Innovation project execution (CT NTF) | Innovation transfer (CT NTF) |
|---|---|---|

**PoF projects**

**Tech-nology scouts**

**Input from divisions**

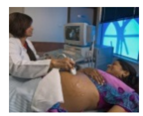
**Input from corporate strategy**

**Business plan**

**Idea assessment**

**Idea memo**


eCar / RACE (I)


Rural Healthcare Solutions India (H)

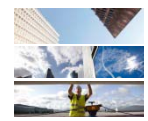

Translational Biotech (H)


Sustainable Cities (IC/E)

…


Electrolyzer (I)


Smart Grid SO EASY (IC)


Situation Control System (Cross-Topic)

…

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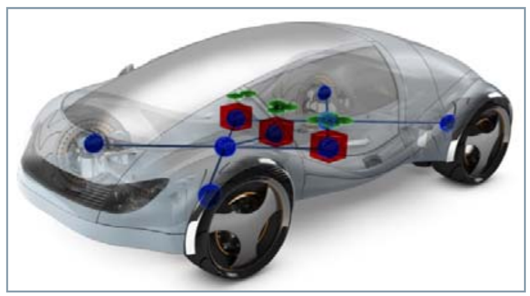
# Major activities performed by CT NTF RACE

**Trusted advisor for all Siemens sectors**
**Development of innovative business models**
**Worldwide relation to leading R&D institutions**



### Smart Grid

- Solutions integrating the electric vehicle into the Grid (V2G)
- Power electronics

### Smart eCar

- ICT[1)] system architecture
- Drivetrains (E-Motors + power electronics)

### Smart Traffic

- Solutions for future intermodal traffic
- Technical test bed for eCar sharing solution

1) Information and Communication Technology

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# How our world is changing
Urbanization


Commuters in Jakarta

## Growth of cities

- **2009:**
  For the first time in history, more than 50% of the world's population lived in cities
- **2050:**
  70% of the world's population will live in cities

## Megacities worldwide

- **1970:**
  2 megacities with more than 10 million inhabitants
- **2025:**
  37 megacities; more than 13% of the world's population will live in a megacity

# How our world is changing
## Demographic change


Morning gymnastics in Shanghai

### World population

- **2012:** 7.1 billion people
- **2050:** 9.6 billion people

### Worldwide life expectancy

- **2012:** 70 years
- **2050:** 76 years
- By **2050**, the share of the population aged 60 or over will, for the first time, equal the share of the population younger than 15

# How our world is changing
## Climate change

Ice sheets off the Icelandic coast

- **2013:**
  Highest $CO_2$ concentration in the atmosphere in 800,000 years
- **2001 to 2010:**
  Warmest decade on record

# Global megatrends strongly influence the future of mobility

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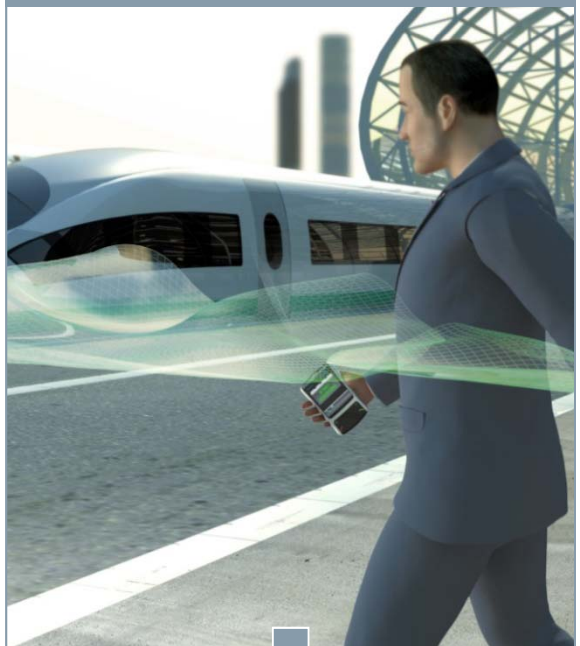
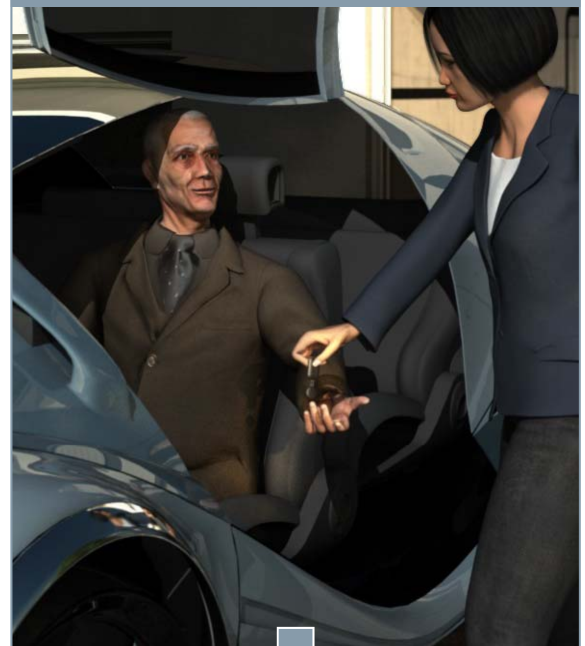
## Climate Change

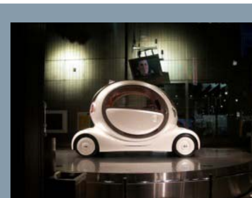
## Urbanization



## Demographic Change



**Will lead to "smart" mobility concepts**





**Vehicle electrification:**
# The full electric drive train allows various suitable drive train configurations with different complexity

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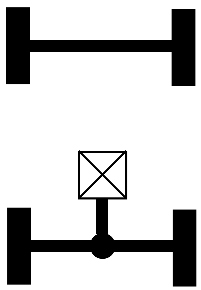
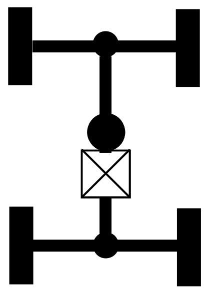


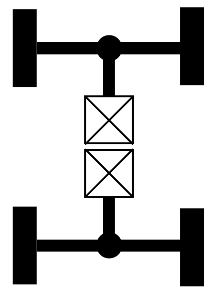
a) 1M-2W

**Advantage**
- Simple
- Similar to today's drivetrain



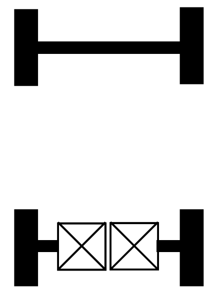
b) 1M-4W

**Advantage**
- 4 Wheel drive,
- Similar to today's drivetrain



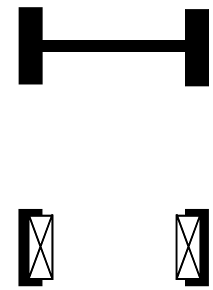
c) 2M-4W

**Advantage**
- Higher power realizable
- No transfer case



d) 2M-2W

**Advantage**
- No differential
- Active torque vectoring



e) 2 IWM-2W

**Advantage**
- No disk brakes on rear axle
- Optimal brake and recuperation strategy
- ASR, ABS with electric machines

# **Vehicle electrification:**
Substitution of mechanical components by electric and electronic systems

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**State of the Art: Brake blending with PSM in-wheel e-motor**

- Peak Power **115 kW**
- Continuous Torque **500 Nm**
- Peak Torque **1,250 Nm**
- Deceleration rate of **0.3g** with recuperation only
- Rear brakes not longer required

**More than 70% of breaking incidents can be performed using only electric machines**

**Vision: "Smart Wheels" enabling fully new vehicle design concepts**

- Motor
- Brake
- Damping
- Steering

# Vehicle automation:
From academic research to major industrial trend


Source: Wikipedia: Google driverless car operating on a testing path

# Vehicle automation
## Vehicle automation increments

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| SAE level | Name | Execution of Steering and Acceleration/ Deceleration | Monitoring of Driving Environment | Fallback Performance of Dynamic Driving Task | System Capability (Driving Modes) |
|---|---|---|---|---|---|
| **Human driver monitors the driving environment** | | | | | |
| **0** | No Automation | Human driver | Human driver | Human driver | n/a |
| **1** | Driver Assistance | Human driver and system | Human driver | Human driver | Some driving modes |
| **2** | Partial Automation | **System** | Human driver | Human driver | Some driving modes |
| **Automated driving system ("system") monitors the driving environment** | | | | | |
| **3** | Conditional Automation | System | **System** | Human driver | Some driving modes |
| **4** | High Automation | System | System | **System** | Some driving modes |
| **5** | Full Automation | System | System | System | **All driving modes** |

Source: SEA International / J3016

# Automation and Electrification require a highly reliable E/E architecture…

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**Driver assistance and automation**

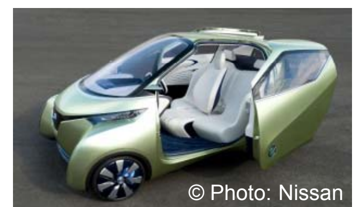
ADAS[1] vertically integrated

ADAS horizontally integrated with strategy level

Partial automation (e.g. intervention to avoid accidents)

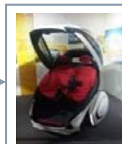
**E/E architectures**

**Smart eCar autonomous driving**




**Electro mechanical integration**

- E-Motor
- Brake
- Damping
- Steering



New vehicle concepts through mechatronic integration

t

1) Advanced Driver Assistant Systems

# … but automotive E/E Architectures are the result of more than 30 years of evolutionary development

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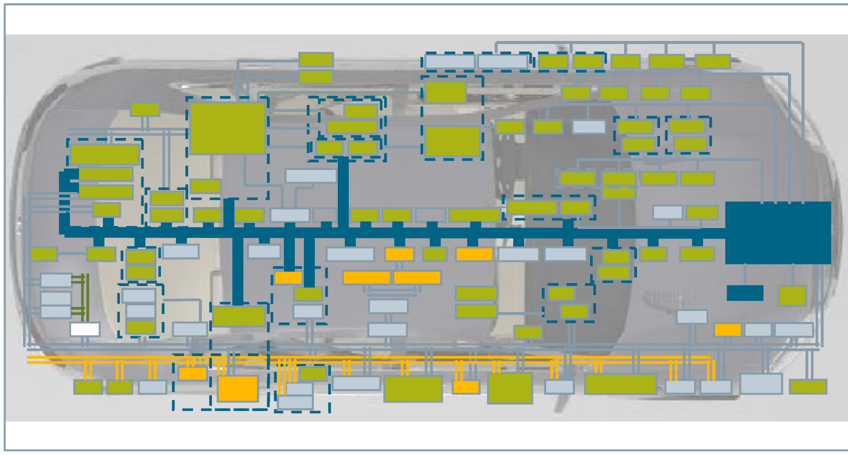
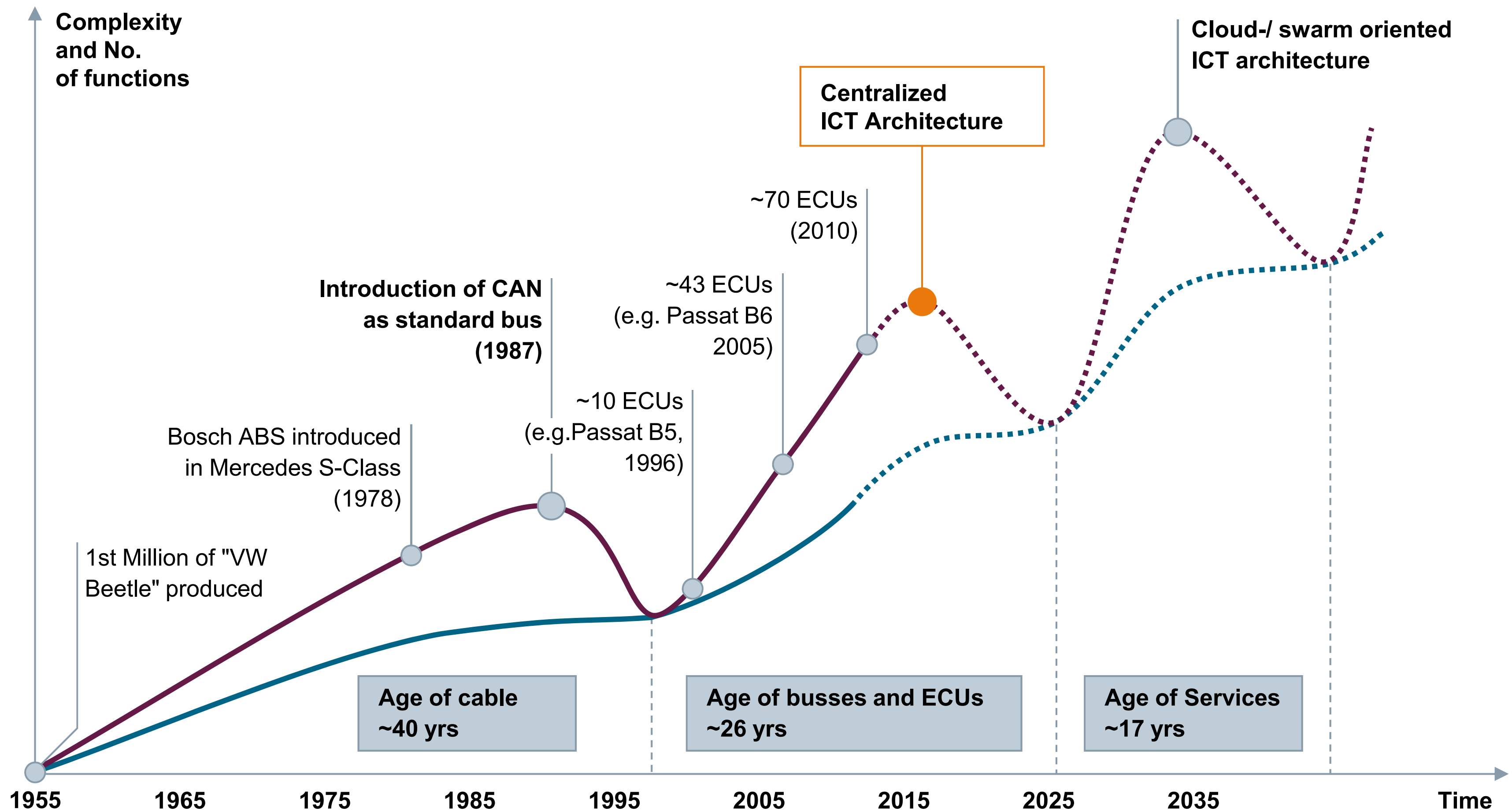


**Consequences:**

- The implementation of new functionality takes **more and more effort, time and complexity**, in particular for cross-domain functionality
- **No global optimization.** Existing solutions are "re-used" over and over again instead of building up an improved architecture from scratch
- **High effort** for test and integration
- **Difficult to enhance the functionality** after delivery (e.g. by SW upgrade, for instance in the infotainment domain)
- Insufficient **reliability,** e.g. for drive-by-wire
- **Cost model based on costs for HW-parts** rather than on long-term considerations for reuse and global optimization

# To reduce complexity the increase of integration based on ICT[1)] principles will be the next step




1) Information and Communication Technology ····· Actual complexity ····· Amount of functions (~necessary complexity)

Source: "The Software Car: Information and Communication Technology as an Engine for the Electromobility of the Future", page 48

# To cope with the challenges of electrification and automation we need a reliable, safe and extensible platform architecture

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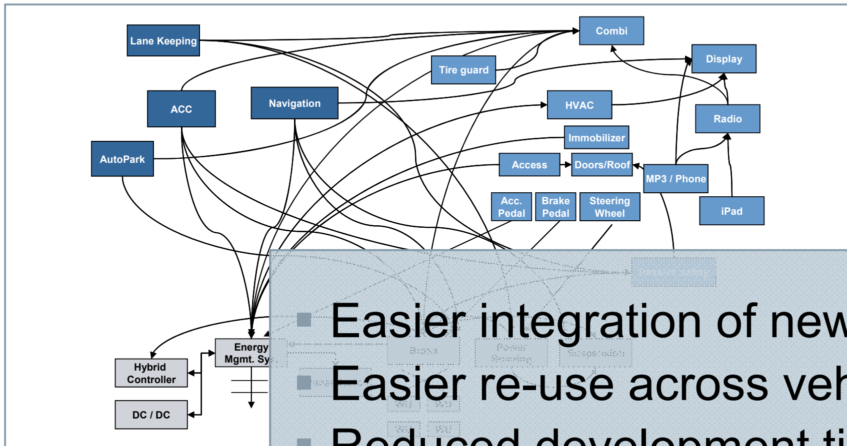
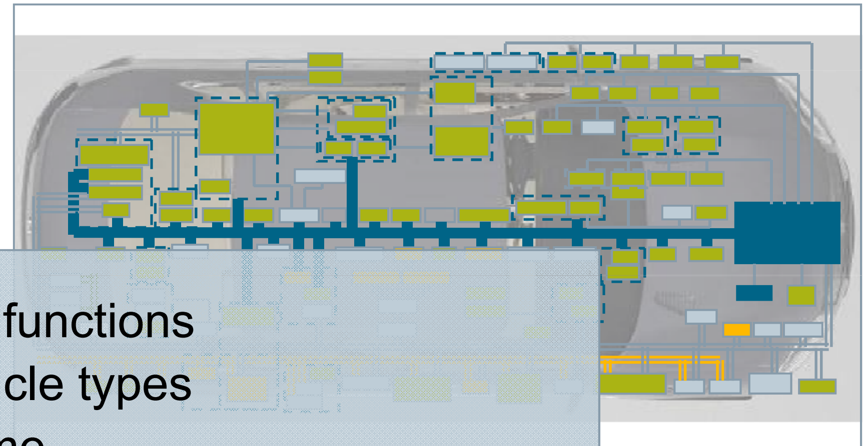
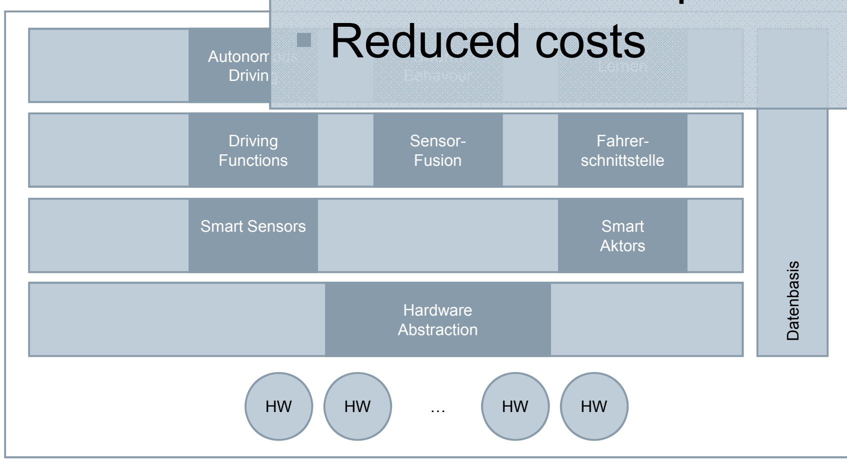
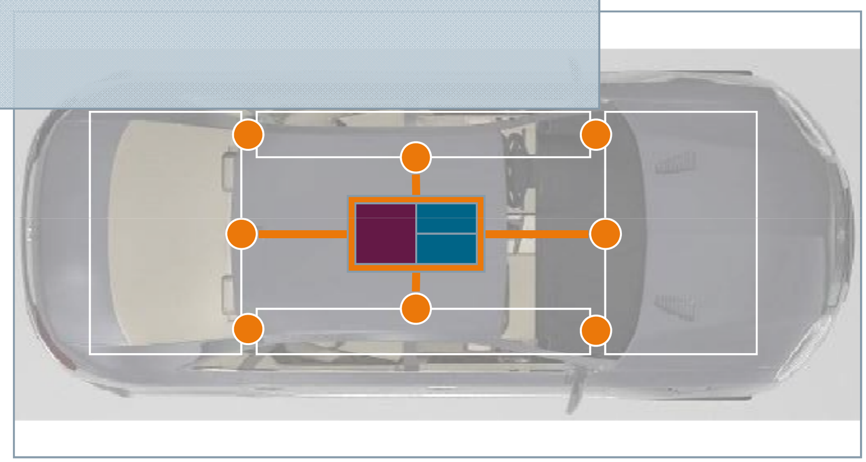


- Easier integration of new functions
- Easier re-use across vehicle types
- Reduced development time
- Reduced costs



# Major Vision: Build an embedded IT platform to realize autonomous driving on top of it

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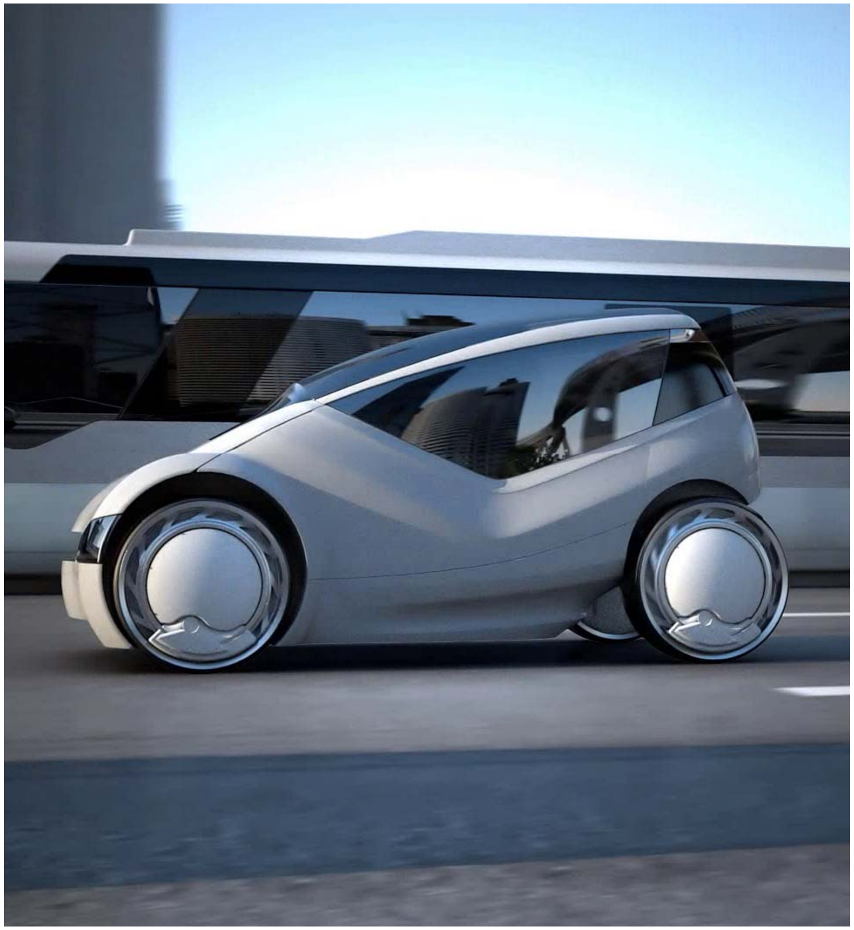

## An embedded IT platform which …

… is still affordable for everyone

**High-Tech for low cost!**

… enables the vehicle to adopt to the needs and habits of changing passengers seamlessly

# Outline

- Research on Electromobility at Siemens CT
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  - Architecture
  - Implementation
  - Demonstrators
- Related work
- Research outlook

# RACE – Robust and reliable Automotive Computing Environment for future eCars

- Funded by the German Ministry for Economics and Energy (BMWi)
- January 2012 – February 2015
- Budget: approx. 20 Mio. Euro
- **Based on the study „The Software Car“**


Bundesministerium für Wirtschaft und Energie

WIRTSCHAFT. WACHSTUM. WOHLSTAND.

| | | | |
|---|---|---|---|
| SIEMENS | TRW | AVL | fortiss innovation in software and systems |
| Universität Stuttgart | TUM | Fraunhofer AISEC | Rheinisch-Westfälische Technische Hochschule Aachen RWTH |

# Project objectives

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| | |
|---|---|
| 1 | Reduction of complexity of the in-vehicle ICT by means of an uniform, open platform architecture |
| 2 | Support of new and complex functions by the ICT-platform (e.g. autonomic charging) |
| 3 | Capability for “Plug & Play” |
| 4 | Show that certification is basically possible |
| 5 | Demonstration of a migration path |

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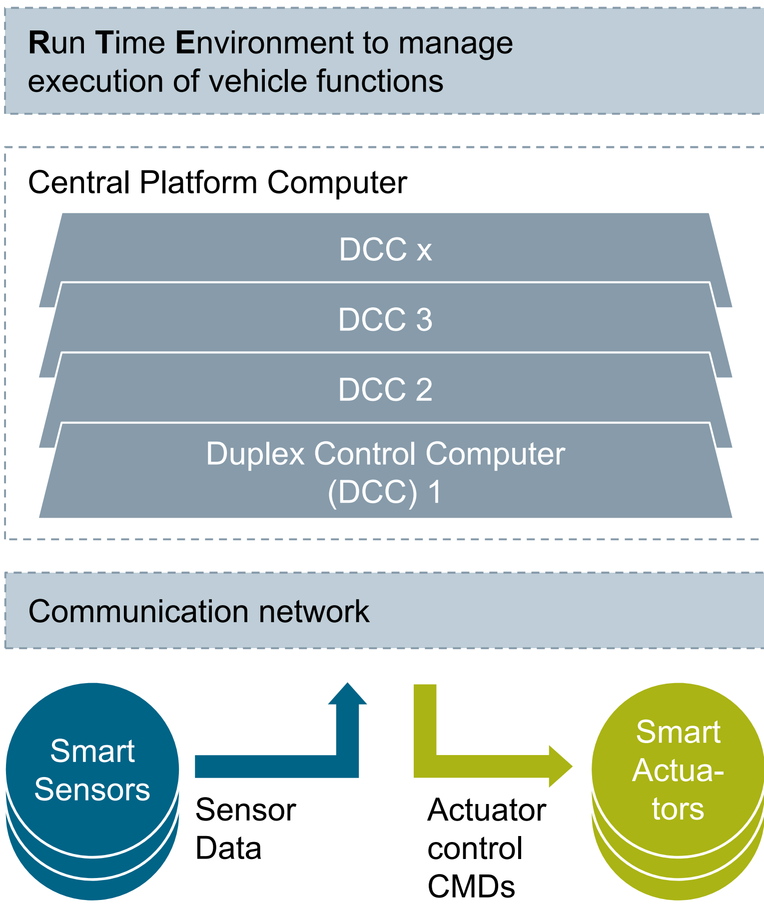
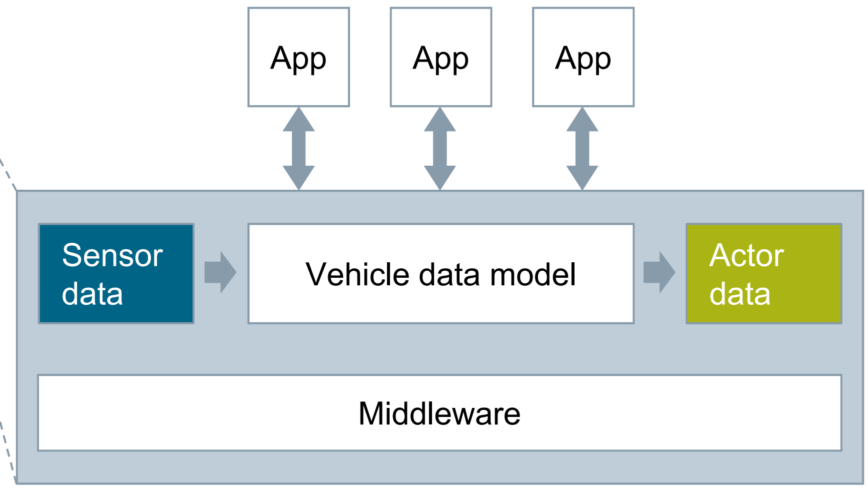
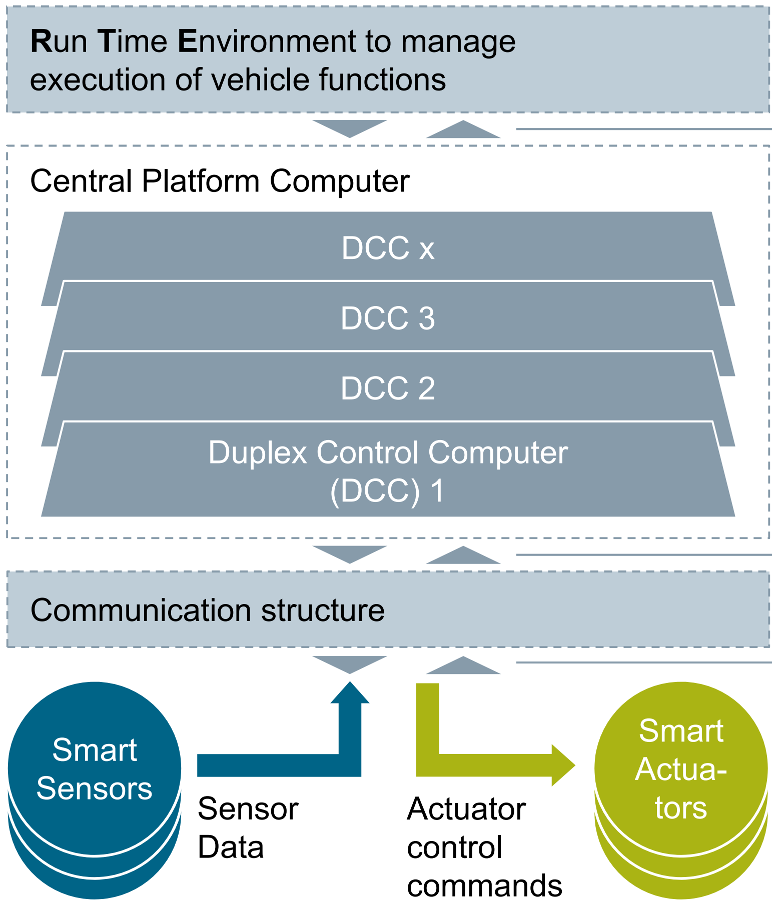
# RACE architecture
# Basic structure and information flow - Overview




1. Scalable central processing units with physical access to all smart sensors and actuators
2. Middleware to decouple vehicle functionality from architecture (including deployment) and BSW-functionality to ensure non-functional qualities (esp. fail-operational service and PnP)
3. Automotive functions

# RACE architecture
# Basic structure and information flow (1/5)



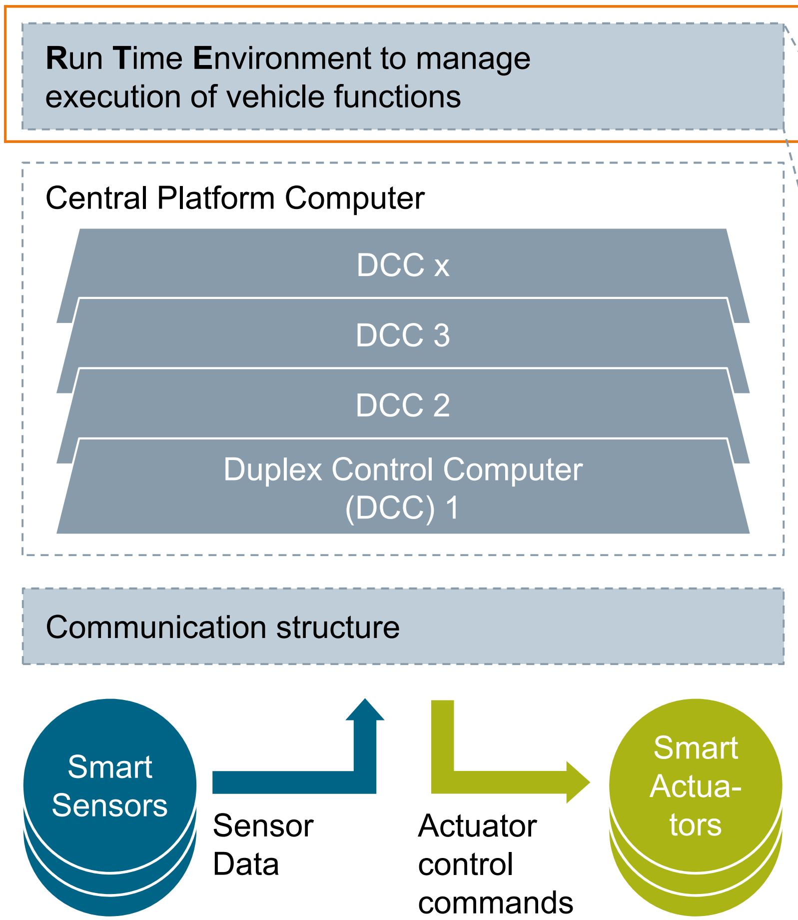

**Implement logical interfaces between…**

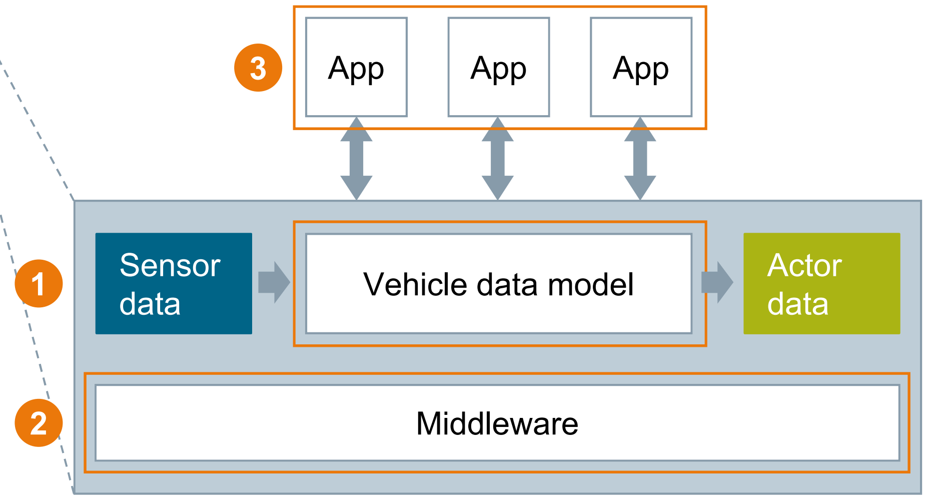
… RTE and hardware.
→ To separate software from hardware

… hardware and network topology.
→ Exchange it w/o hassle if mandatory

… network and (smart) sensor/actuators.
→ Update and add hardware at any time

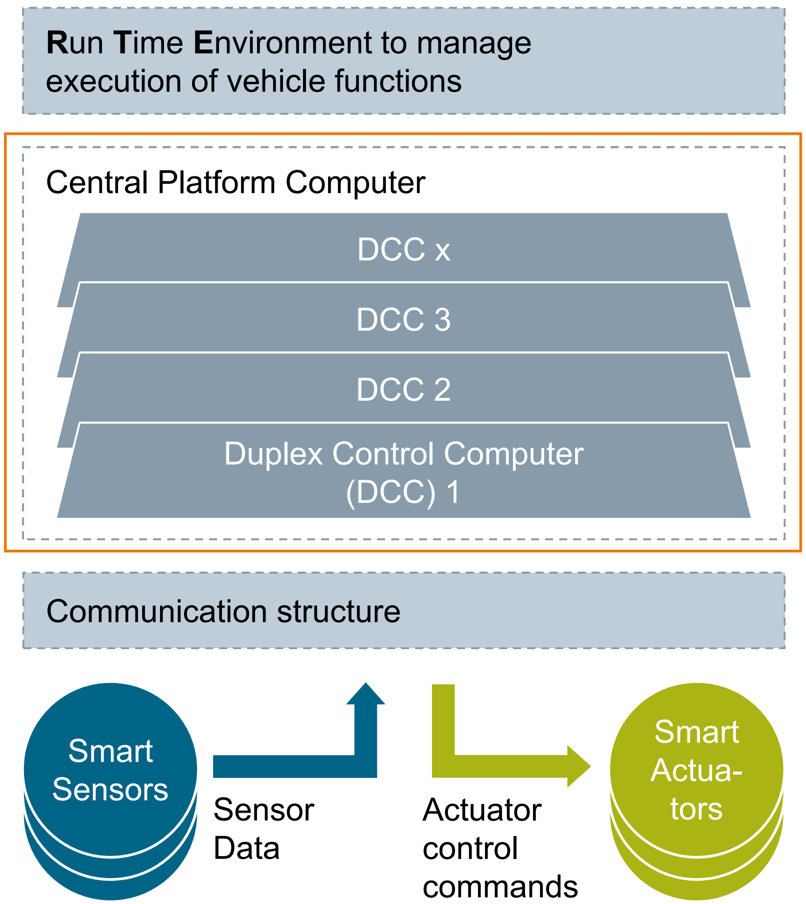
# RACE architecture
## Basic structure and information flow (2/5)




1. (Virtual) connection between sensors/actuators and Apps dynamically generated
2. QoS assurance: Fail-operational, abstraction of sensors/actuators, Plug & Play management
3. App-Code and description of dependencies separated but in one binary. Safety-management **not** included

# RACE architecture
# Basic structure and information flow (3/5)




**Fail-operational service**

→ Dynamic reconfiguration within given fault-tolerance times

**Virtualized hardware (RTE's perspective)**

→ Scale performance seamlessly
→ Vehicle computers instead of domain controllers

# RACE architecture
# Basic structure and information flow (4/5)

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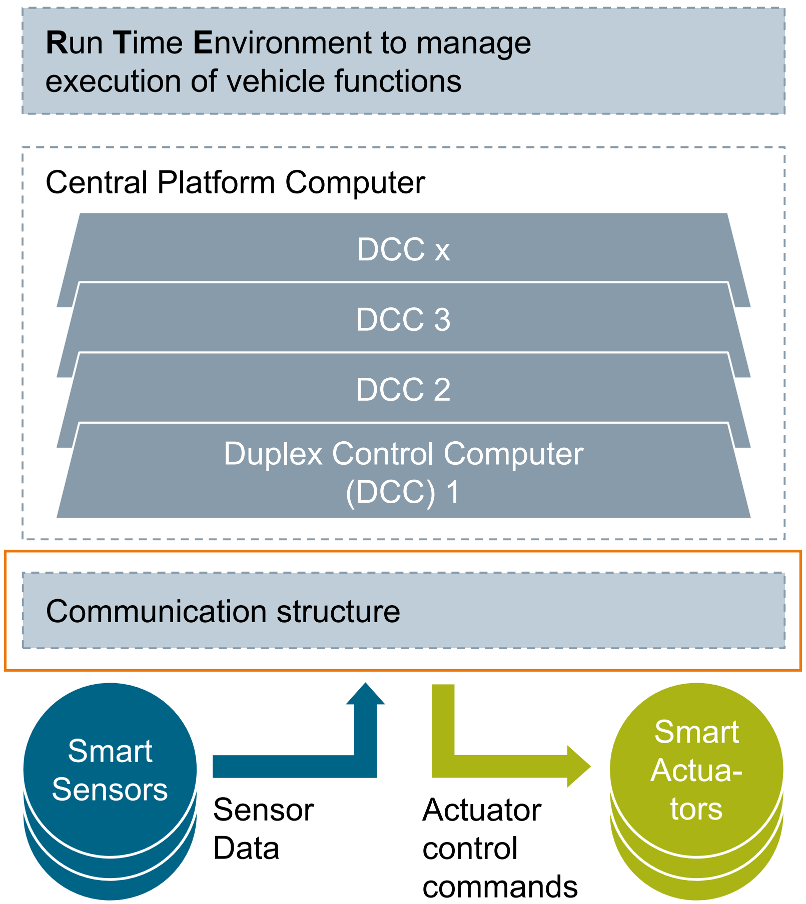


**Quality of service**

→ No single point failure will lead to loss of function

**Guarantee end-to-end security**

→ Only certified hardware can push data over the network

**Plug and play capability**

→ Self organizing network ensures quality of service

# RACE architecture
# Basic structure and information flow (5/5)

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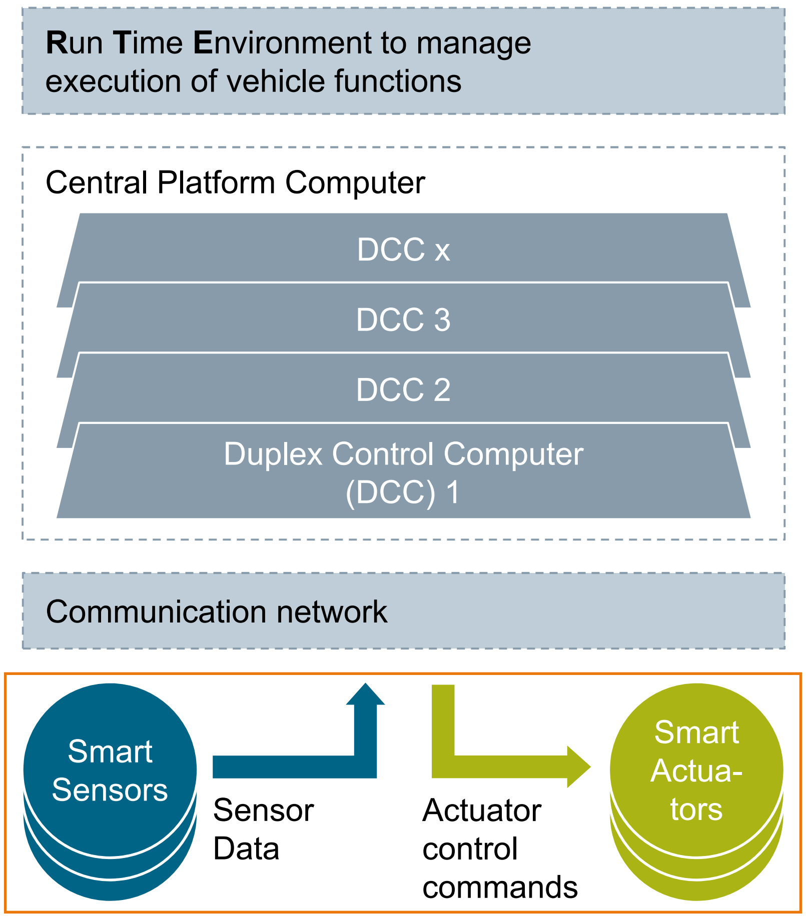
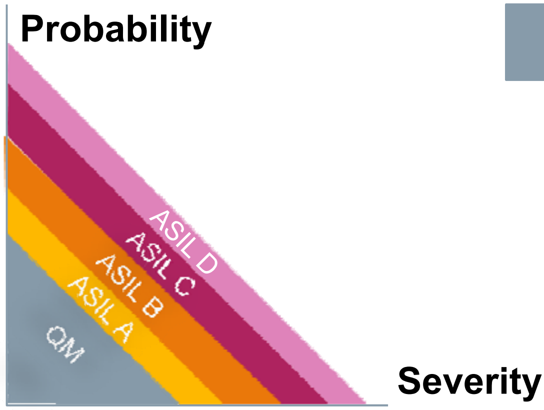



**Local intelligence to execute open-loop and closed-loop control tasks**

→ A wheel hub motor detecting the maximum torque by itself
→ A video camera generating an object list

# RACE safety considerations
# Application of the ISO 26262

Acc. To TÜV SGS-documents




**Hazard & Risk (H&R) assessment**

**ASIL ≥ A**

No → Development acc. to standard-process

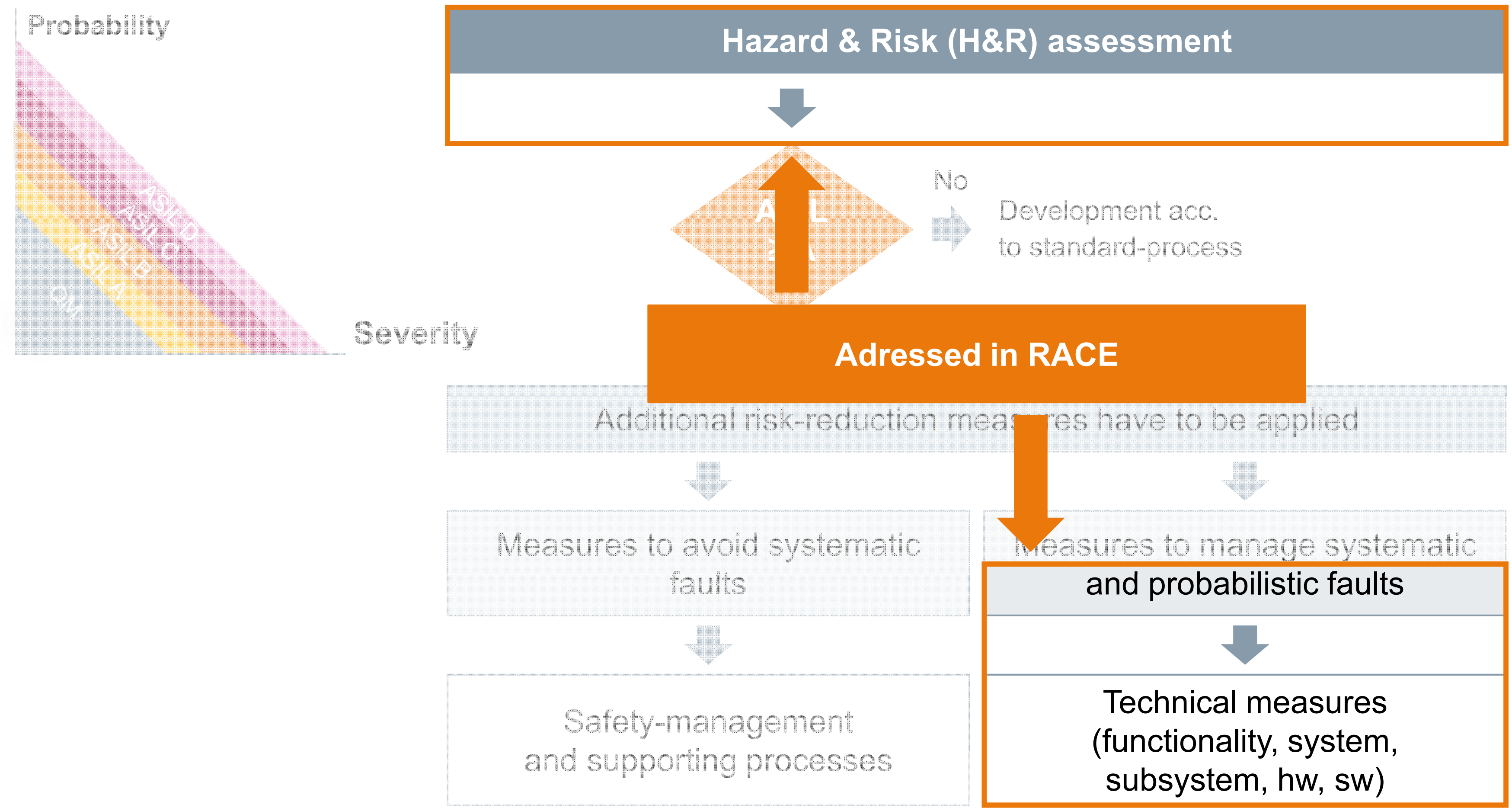
Yes ↓

Additional risk-reduction measures have to be applied

| | |
|---|---|
| Measures to avoid systematic faults | Measures to manage systematic and probabilistic faults |
| Safety-management and supporting processes | Technical measures (functionality, system, subsystem, hw, sw) |

# RACE safety considerations
# Application of the ISO

Acc. To TÜV
SGS-documents



# RTE: Functionality and quality

| Topic | Aspect | Requirements |
|---|---|---|
| Vehicle Control computers | Execution | • Execute applications with real-time guarantees,<br>• Supervise & control resource demands |
| | Communication | • process I/O to/from aggregates, inter-app communication |
| Generic safety up to fail-operational | Integrity | • detect failures in data received / sent<br>• configurable performance calculation for apps & data |
| | Availability | • ensure availability of data and applications<br>• provide configurable default values |
| | Reliability | • shield systematic application faults<br>• detect and isolate sporadic HW errors |
| | Testability | • runtime data accessible in real-time (observation points)<br>• Manipulate all data accessible in real-time (control points) |
| Plug & Play | Configurability | • calculate new config. of RTE data flow and app. Execution<br>• data / control paths as configuration data<br>• system data model as basis for self-configuration |
| | Ease of engineering | • Dictionary-based interface model<br>• App development independent of RTE configuration |

# Outlook:
# „Plug & Play“, based on data-centric communication

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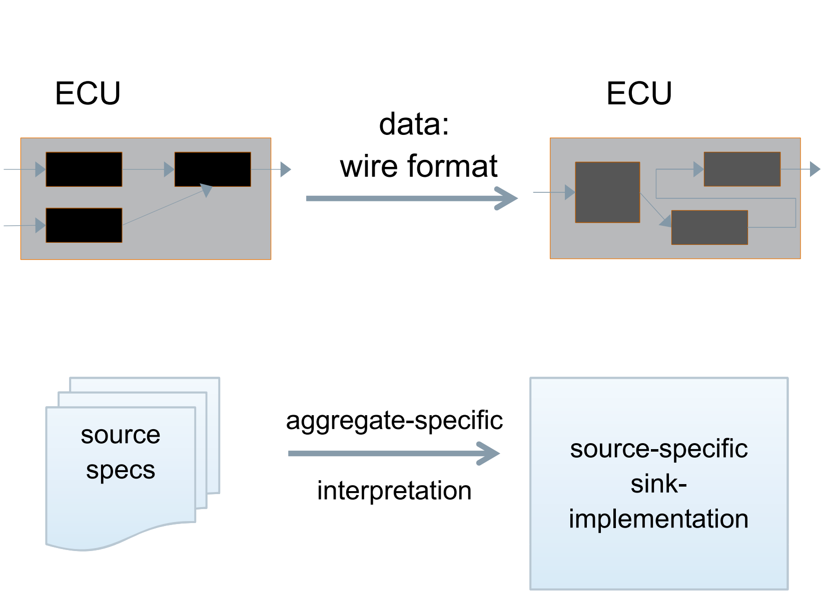
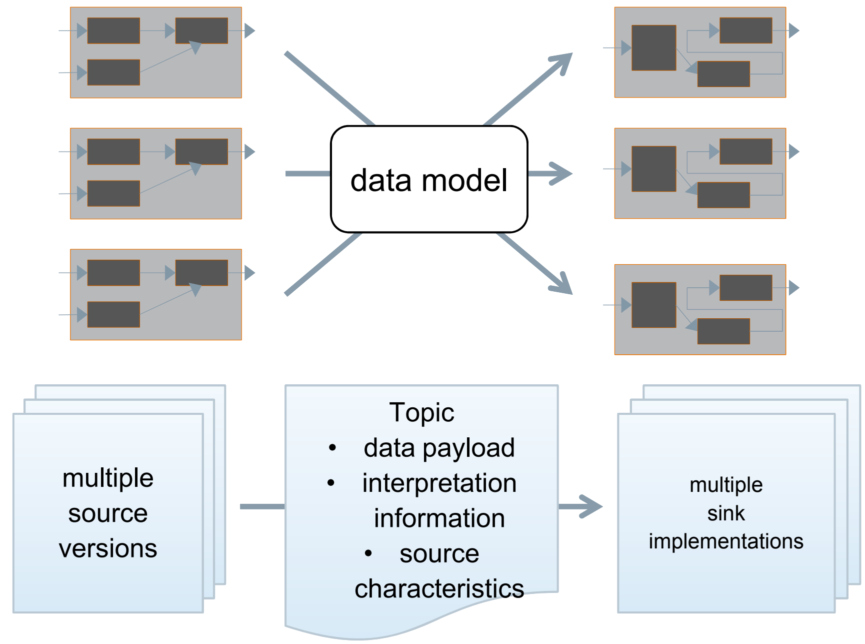



**Classic Approach:** Aggregate-Centric

- Data is interpreted using knowledge about the source
- Dependent on (informal) knowledge
- **Tight coupling** of aggregates and aggregate developers needed
- Inflexible, **hard to build modular architectures**



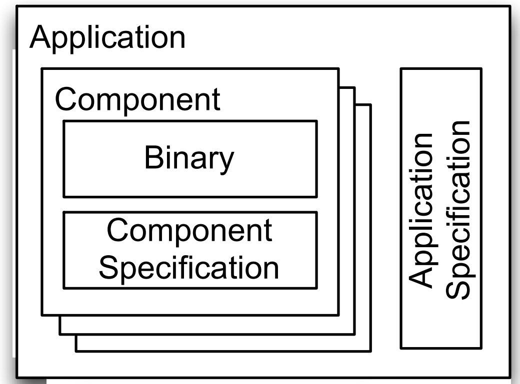

**Novel Approach:** Data-Centric

- The source properties are reflected in the topic **attributes**
- Data can be interpreted solely relying on the topic description
- **Decoupling** of producer and consumer of data
- **Flexible**, enables **modular** architectures

# Plug & Play:
# Application deployment and reconfiguration

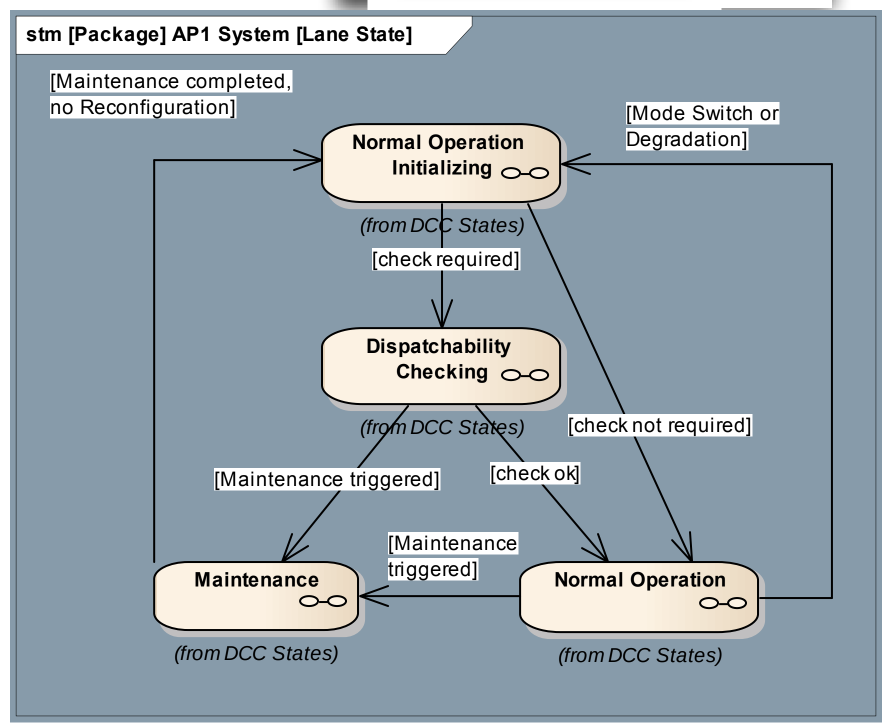
**Application bundle as product:**

- Applications are delivered together with specifications (so called Manifests) about their functional and non-functional properties and requirements
  - WCETs, required memory
  - required and provided data




**Reconfiguration process:**

- calculation of potential new deployments at runtime
- restricted to safe state, i.e. maintenance mode in parking position
- if valid configuration is found, switch on all nodes to this configuration (guaranteed by RACE platform consistency)



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# RACE implementation: Prototypes of vehicle ECUs

- Initial prototype implementation to demonstrate the concept
- Limited safety mechanisms implemented
- Not suitable for public roads

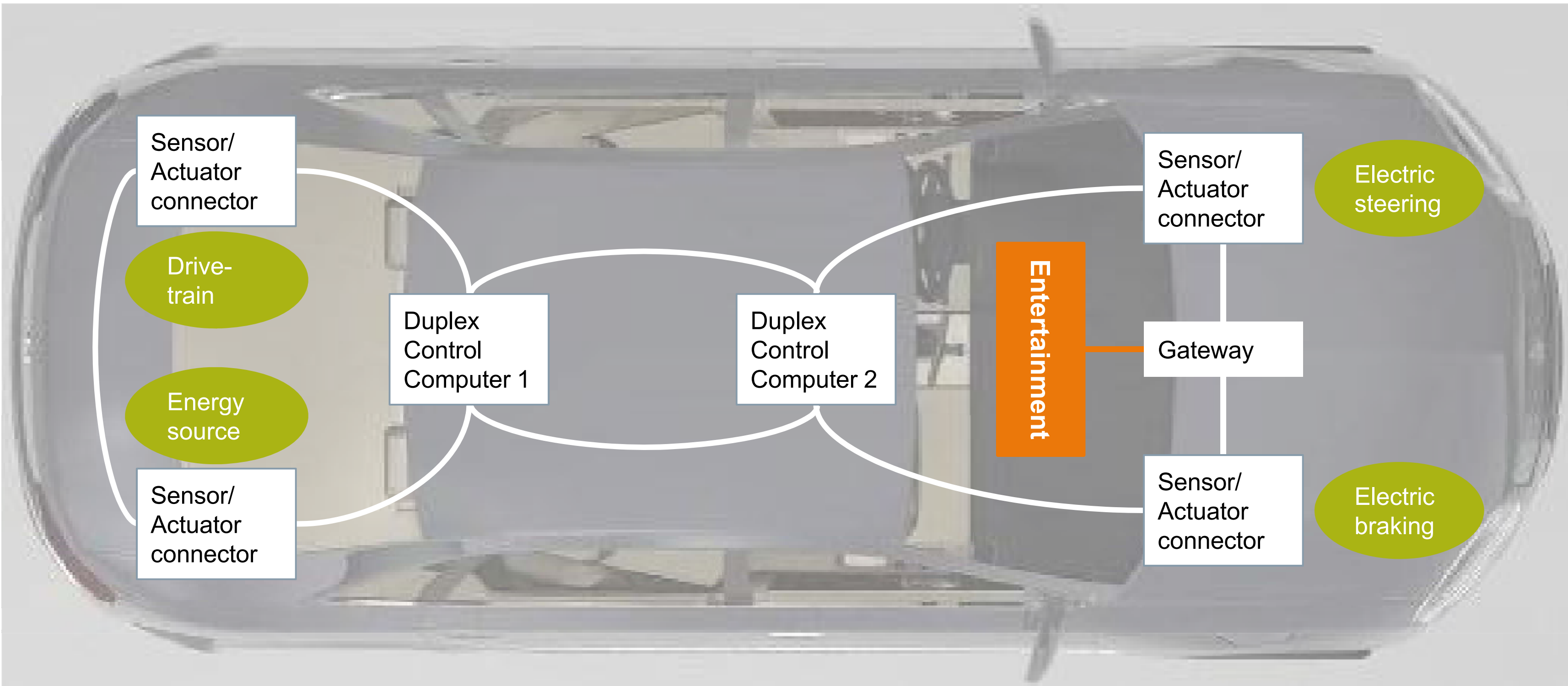
**Duplex Control Computer (DCC)**:

- „Dual lane“, d.h. 2 CPUs + Ethernet-Xlink
- 4 * RACE Ethernet, 2* Test Ethernet

**Gateway (GW)**:

- 1 CPU
- I/Os (CAN, LIN, Digital und Analog I/O)
- 2 * RACE Ethernet, 1 * Test-Ethernet

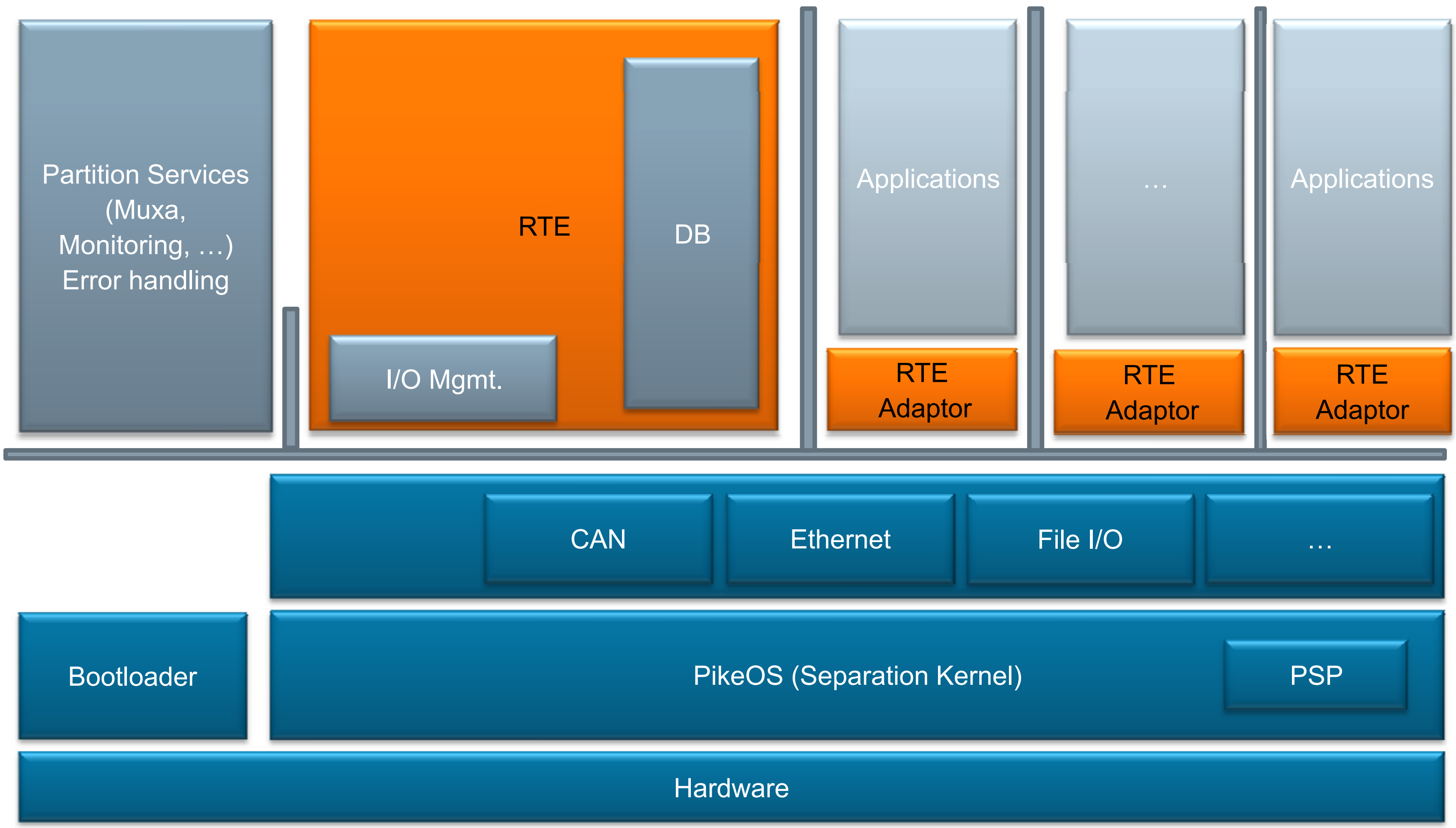
# RACE implementation:
# Ethernet-based redundant communication backbone




- Ethernet: AVB Gen 2 / Time Sensitive Networking
- Derived from IP from Siemens Industry
- Ingress/egress rate limiting to isolate malfunctions (babbling idiot)
- Large frame buffers to minimize/eliminate interrupts

- Hardware support for the Precision Time Protocol
- Redundancy by using directions:
  - Inner Ring for DCCs
  - Outer Ring for Sensors and Actuators
- Mixed criticality

# RACE implementation: Using PikeOS to prevent fault propagation



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# Outline

- Research at Siemens CT
- Reasons for a radical change in automotive E/E architectures
- The RACE project
  - Architecture
  - Implementation
  - Demonstrators
- Related work
- Research outlook

# RACE demonstrators
# Revolution vs. Evolution

Demonstrate a migration path

**Reduction of ICT architecture complexity** + **Proven functionality of ICT architecture**

**Development of 2 Prototypes**

**"Migration/Evolutionary Car"**

- Based on standard production vehicle
- A selection of functions (e.g. lateral and longitudinal dynamics, energy mgmt.) are built on new ICT architecture
- All other functions still based on traditional E/E architecture
- New and traditional architecture are connected via gateways

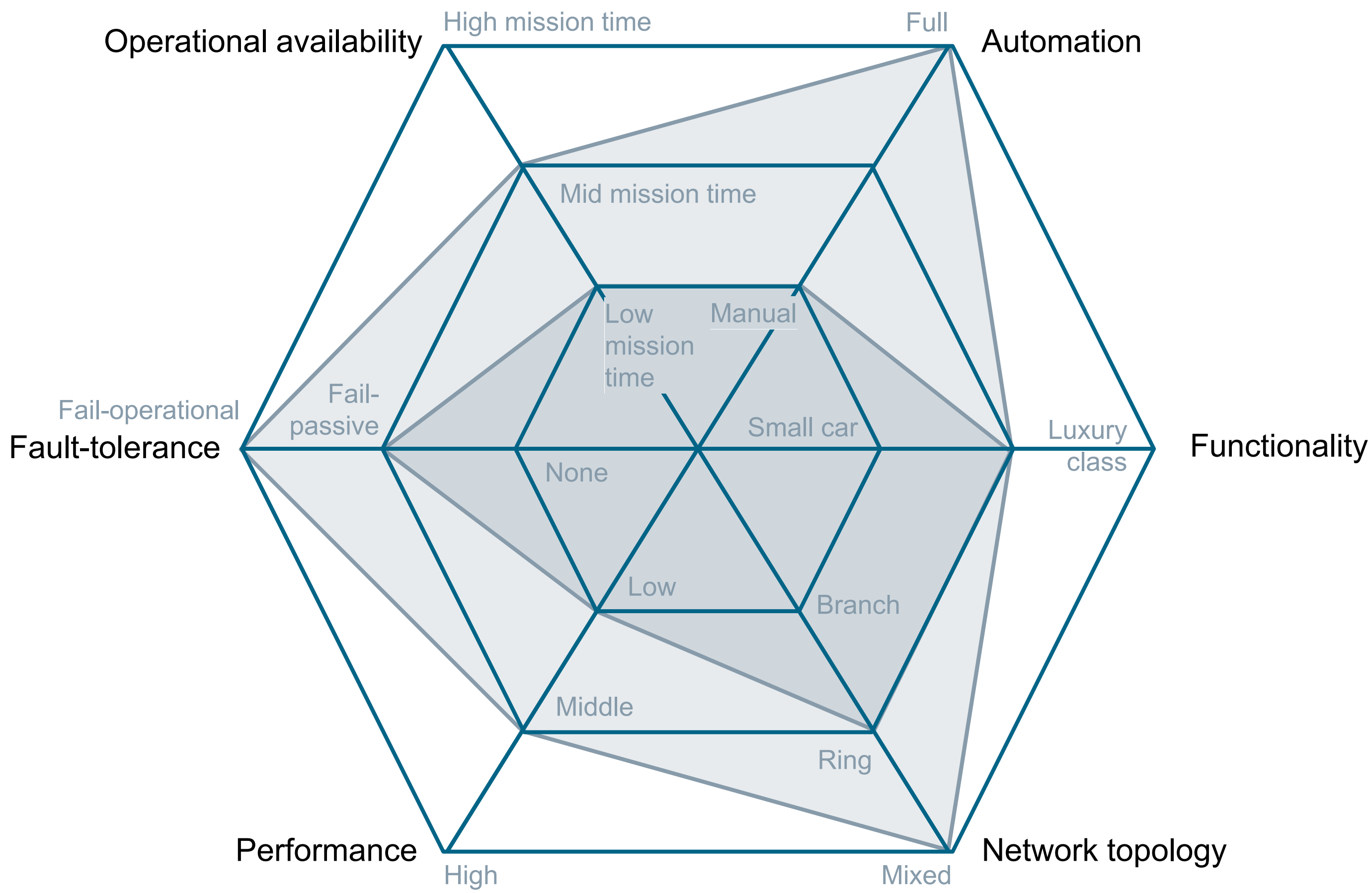
All standard vehicle functions are available. **Selected functions** are based on new architecture.

**"Revolutionary Car"**

- Based on a more unconventional vehicle
- All functions (e.g. acceleration, deceleration, energy mgmt., HMI) are built on new ICT architecture
- No integration of functions based on traditional E/E architecture
- Selected hardware components connected via gateway as needed
- Goal is true Drive-by-Wire on redundant electronics

**All** functions are based on the **new system architecture**. But only a **subset** of possible functions are implemented.

# Scaling the RACE Platform




— Evolutionary car — Revolutionary car

# RACE Demonstrators & Evaluation:
„Revolutionary Car“- Roding Roadster Electric with full X-by-wire architecture

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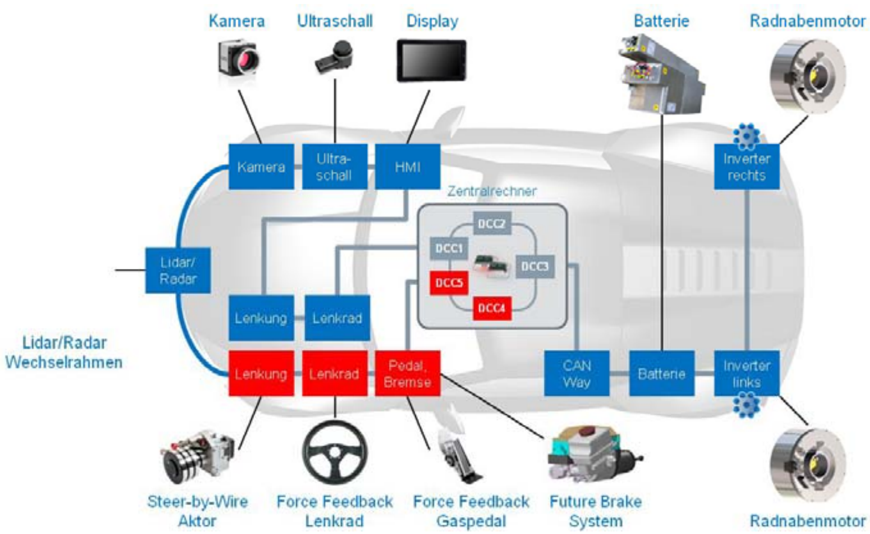



## Chassis

- Carbon/ Aluminium light weight construction
- Total weight: 1.250 kg

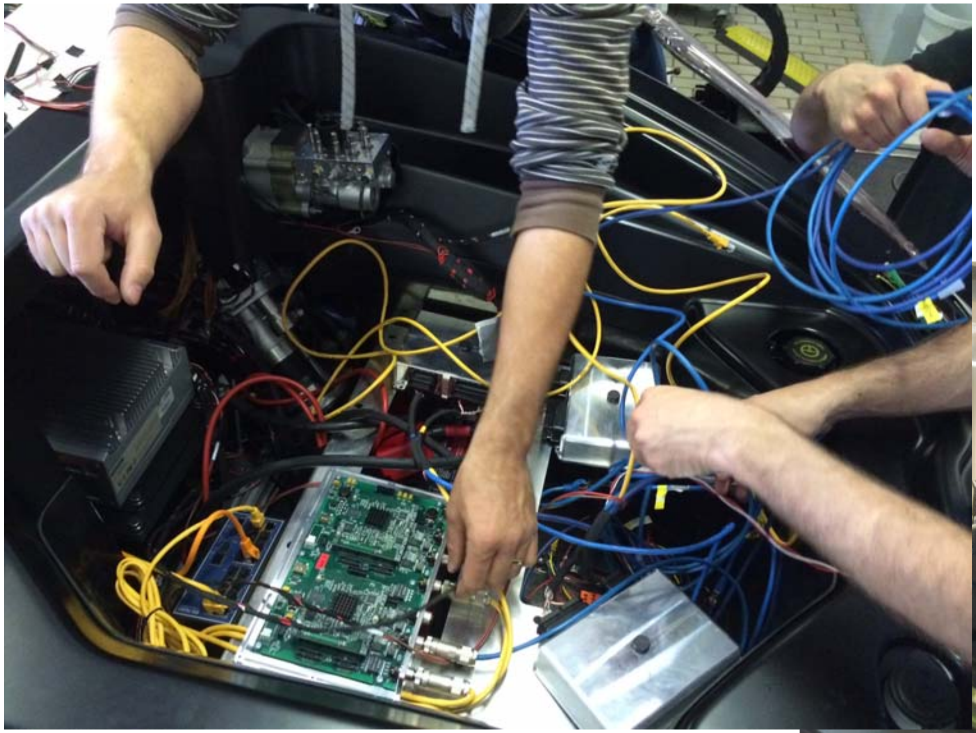
## Drive train, braking and steering:

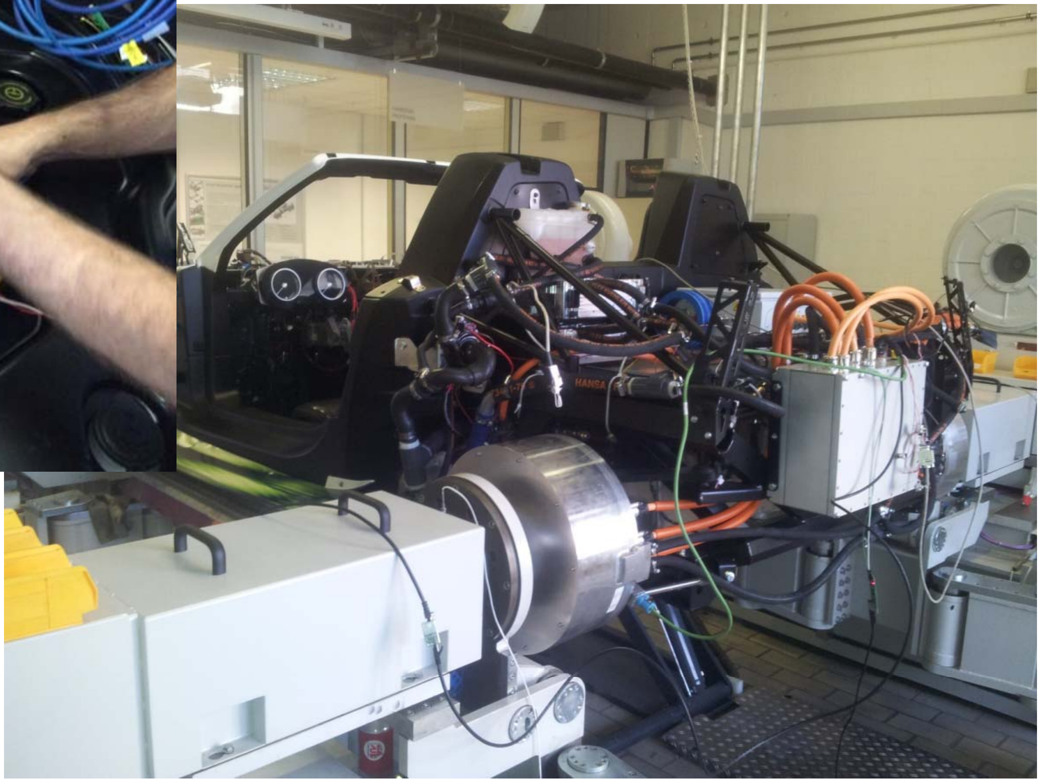
- 2 Wheel hub motors
- Electric braking system „Future Brake System“ (TRW)
- Steer-by-Wire without mechanical fallback (Paravan)

## E/E architecture

- Redundant design, based on RACE
- Ethernet ring structure
- Use of „Gateways“ for connecting HMI, sensors and actuators

# RACE Demonstrators & Evaluation:
Vehicle integration in Lab





# RACE Demonstrators & Evaluation:

## Evolutionary Car- Collaboration with Streetscooter


Gemeinsame Presseinformation **Presse**

**von Siemens und StreetScooter** München, 17.07.2014

### Siemens rüstet Elektroauto von StreetScooter mit neuartiger Elektronik und Software aus

- **Rechnerarchitektur steuert alle Funktionen im Auto – analog zu Technologien aus der Luftfahrt**
- **Funktionen wie Fahrerassistenzsysteme schnell und kostengünstig per „Plug & Play hochladen"**

Die zentrale Siemens-Forschung und der Elektrofahrzeughersteller StreetScooter haben heute vereinbart, ein Elektroauto mit einer neuartigen Elektronik- und Software-Architektur auszurüsten. Die Technologie wurde im Rahmen des RACE-Projekts entwickelt. RACE ist ein vom Bundesministerium für Wirtschaft und Technologie gefördertes Forschungsprojekt, bei dem Siemens Konsortialführer ist. Damit wird es erstmals möglich sein – ähnlich dem „Plug & Play"-Prinzip am heimischen PC – Funktionen wie elektrisches Bremsen oder Systeme wie Spurhalteassistenten nachzurüsten. Bis Dezember 2014 wollen die Unternehmen im Siemens-Forschungszentrum München-Neuperlach die RACE-Architektur in einen elektrischen Lieferwagen integrieren. Ziel der Kooperation ist es, die neue Technologie erstmals in der Praxis zu testen.

„Wir glauben, dass RACE ein erhebliches Potenzial bietet und den Aufbau künftiger Autos revolutionieren könnte", sagt Prof. Armin Schnettler, der bei Corporate Technology, der zentralen Siemens-Forschung, das Projekt verantwortet. „In Zukunft erwarten wir einen Einsatz von standardisierter Hardware und flexiblen

SIEMENS STREETSCOOTER

**Siemens AG**
Wittelsbacherplatz 2
80333 München
Deutschland

**StreetScooter GmbH**
Jülicherstr. 191
52070 Aachen
Deutschland

Informationsnummer: AXX201407.53 d Seite 1/3

# **RACE Demonstrators & Evaluation:**
Rapid implementation of new features

"Evolutionary Car" – Show the benefits for a manufacturer of commercial vehicles

**Zeit**

| **Today** | **New (based on RACE)** |
|---|---|
| New driving function | New driving function (in our example: PCU – power) |
| Request to supplier/development contract | Development and test on top of the RACE platform |
| Supplier | Install new SW |
| New ECU | Test |
| Vehicle integration and test | race & |

**Insourcing (Increase value-add), Reduced development time, more flexibility**

# RACE Demonstrators & Evaluation:
Integration into series car

# RACE Demonstrators & Evaluation:
Students competition

**Students competition:** Four teams from the TUM chair of computer science (Prof. Broy) developed four new applications using the RACE base system (2 month w/o prior experience).

User Space

**Remote control**

**Facebook reward system**

**Monitoring RACE informations**


**Traffic signs recognition**

**New components** implemented on RACE

← HW →

**Components** e.g. camera

← Software →

**Object detection**

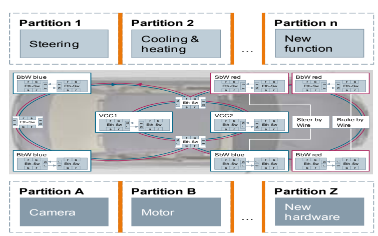
**Neural network**

**Data interface for HMI**

**Data interface for Facebook**

**Control app for remote driving**

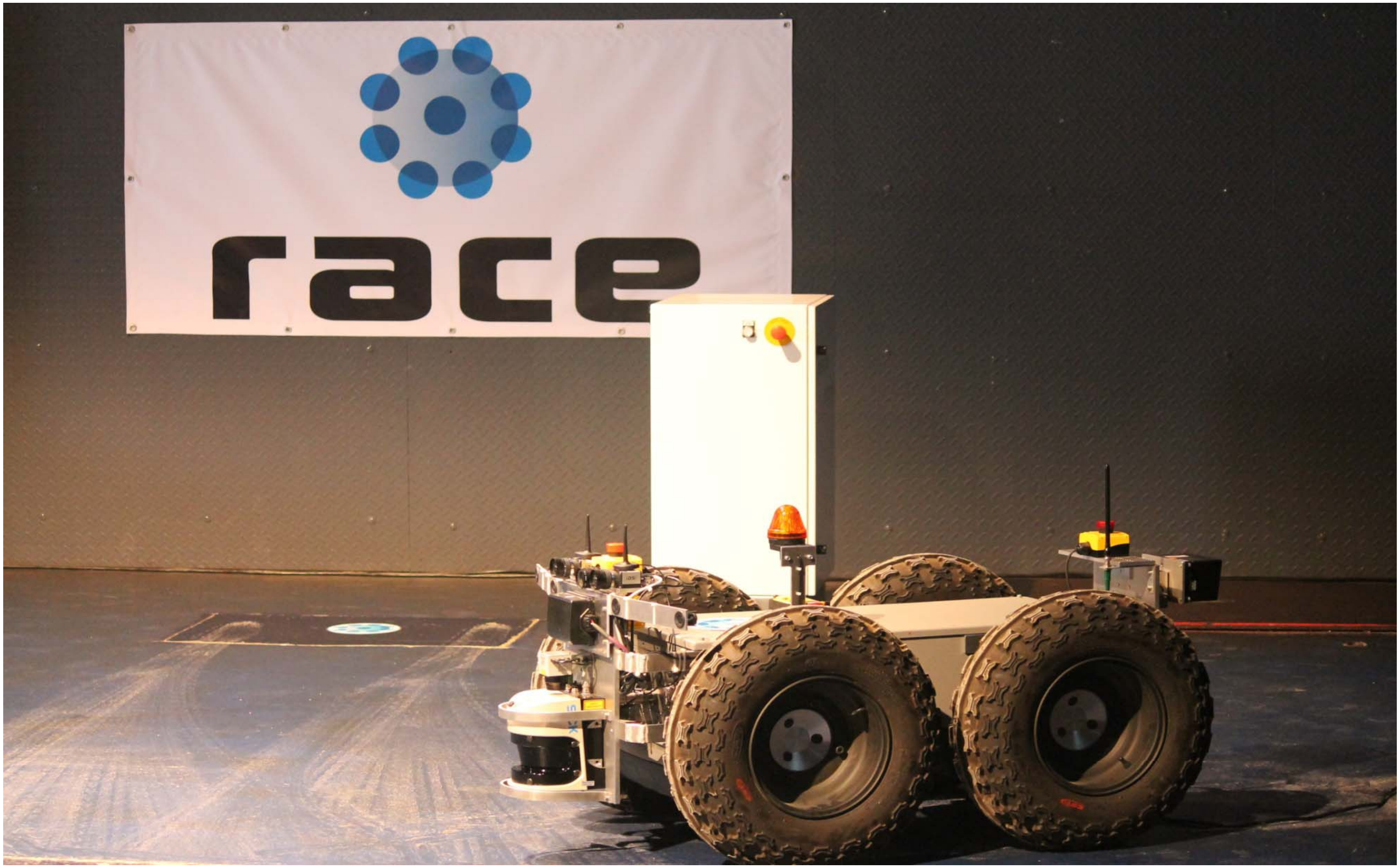
System Space




RACE base system

Picture sources:
http://www.wired.co.uk/news/archive/2013-09/09/remote-control-animals
http://www.crutchfield.com/S-k9jtvTNOTdd/p_150MECH/Garmin-Mechanic-with-ecoRoute-HD.html
http://sinsel.files.wordpress.com/2007/03/road_signs.jpg

# RACE Demonstrators & Evaluation:
Automated parking



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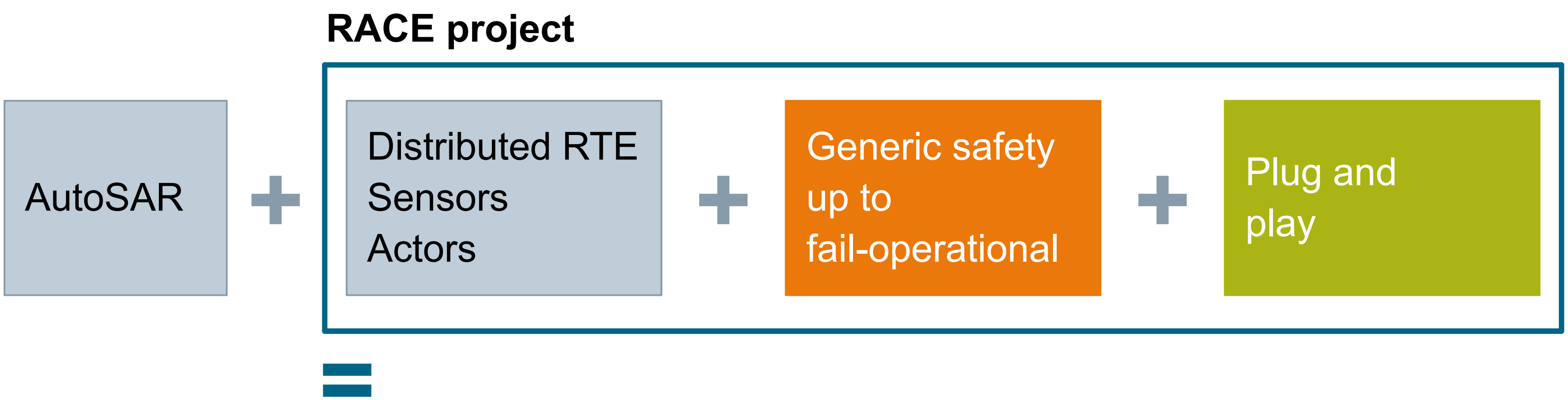
# The vision of the future ICT system platform AUTOSAR vs. RACE

- AUTOSAR is an open standards for automotive E/E architectures that provides a basic infrastructure to assist with developing vehicular software
- The RACE concept is based on a holistic approach with an extensible platform addressing non-functional qualities




**Future ICT system platform**

# FP7 Project "SafeAdapt": Safe Adaptive Software for Fully Electric Vehicles

SIEMENS

## Motivation

**Strong need for a new software architecture for safety-critical systems in FEVs**

- Improving robustness and energy consumption
- Adaptation is essential for a new architecture
- Adaptation is challenging due to safety concerns

## Project objectives

**Safe and controlled adaptation for the complex, networked control systems in EVs**

- Enhanced SW architecture for electronics in fully electric vehicles (based on AUTOSAR)
- Update and re-organize SW @ runtime
- Safe adaptation core encapsulating adapation mechanisms

## Key figures

| | |
|---|---|
| Call: | FP7-2013-ICT-GC (STREP) |
| Project duration: | 07/2013 – 06/2016 |
| Total costs: | EUR 9.2 million |
| EU funding: | EUR 5.9 million |
| Project Website: | http://www.safeadapt.eu/ |

SafeAdapt

## Consortium

- Fraunhofer ESK (Coordinator)
- TTTech Computertechnik AG
- Fico Mirrors S.A.
- Fundación Tecnalia Research & Innovation
- CEA List
- Siemens AG, Corporate Technology
- Pininfarina SPA
- Duracar Holding B.V.
- AWEFLEX Systems B.V.
- Delphi Deutschland GmbH

# Outline

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# Conclusion

- The electrification of vehicles and the trend towards automated require highly reliable E/E architectures.
- The existing E/E architecture is historically grown. It can not fullfil this requirement and makes the implementation of new functions a high effort
- RACE has demonstrated the feasibility of a new„„revolutionary“ approach. The main results are:
  - A runtime environment and a HW platform for safety up to ASIL-D
  - Vehicle demonstrator „Revolution” – Fail-Operational for Steer-by-Wire and automated driving
  - Vehicle demonstrator „Evolution“” – Reduced time and effort for function development in series production cars
  - Demonstrators showing particular aspects (Automation, ease of SW development)
- RACE will be further developed for automotive use and other application domains

# Future research topics

- Reduction of effort for engineering and configuration up to „Plug&Play“ even for safety-critical functions and components
- Open and extensible models for representing sensor information (from in-vehicle sensors, traffic infrastructure or other cars)
- Functional architecture for re-use of automation and driving functions across vehicle types
- Validation and test of automation functions
- Methods and tools for agile development of safety-critical functions
- Enabling technologies, such as
  - Optimized bord net architectures
  - Smart sensors and actuatores
  - Safe, secure and robust communication technologies (in-vehicle, V2X)

# Thank you for your attention!