Dependable Autonomous Vehicle Architectures

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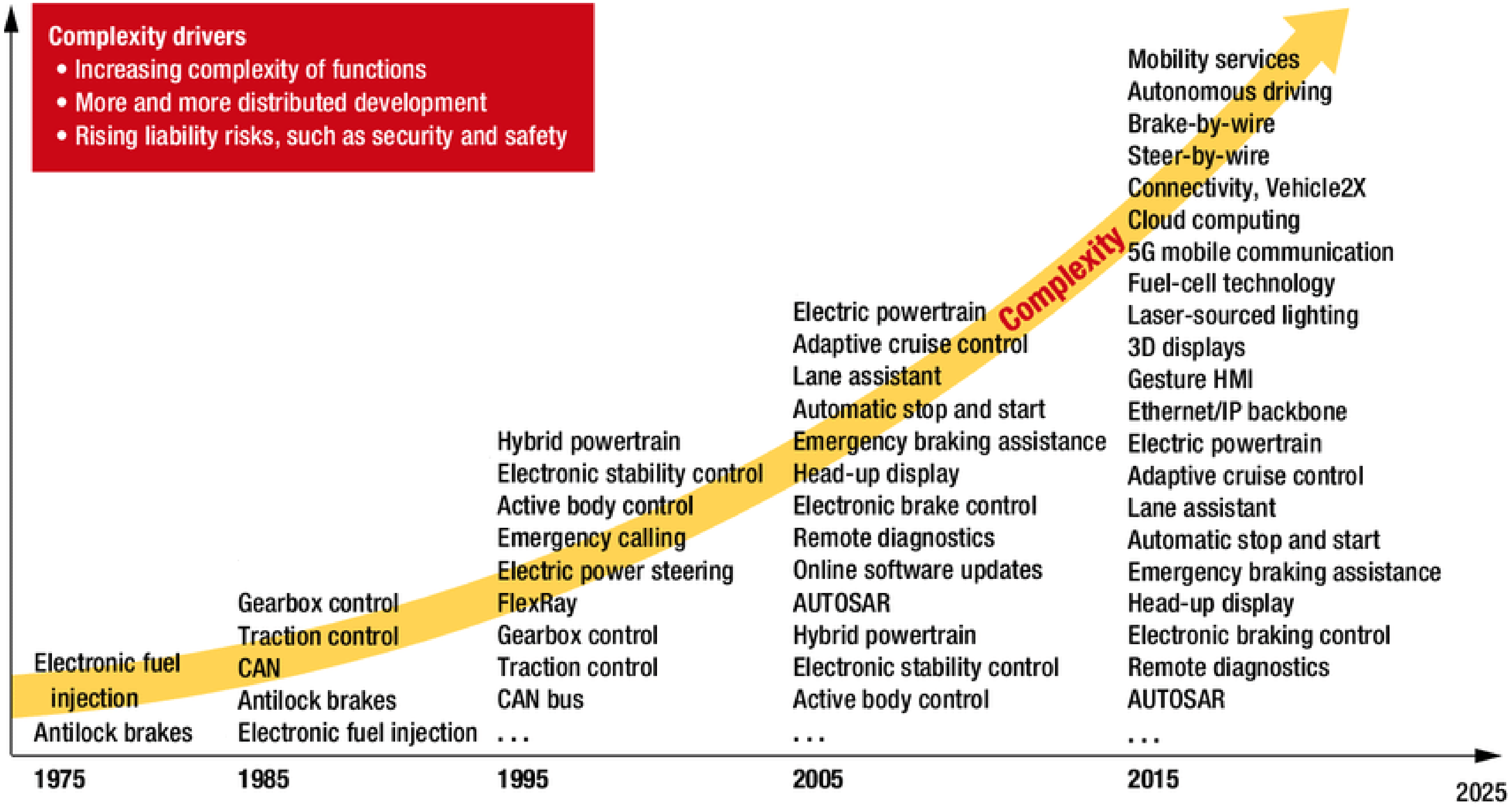
Outline

- Evolution of vehicle electronic platforms
- Dependability challenges: real-time and safety-critical
- Example configuration problem: mapping and scheduling
- Example research projects at DTU Compute

Increasing complexity (automotive software)

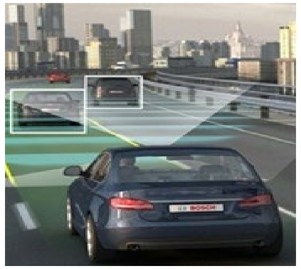


6 levels of autonomous driving

	LØ No Automation	L1 Driver Assistance	L2 Partial Automation	L3 Conditional Automation	L4 High Automation	L5 Full Automation
DRIVER	In charge of all the driving	Must do all the driving, but with some basic help in some situations	Must stay fully alert even when vehicle assumes some basic driving tasks	Must be always ready to take over within a specified period of time when the self-driving systems are unable to continue	Can be a passenger who, with notice, can take over driving when the self-driving systems are unable to continue	No human driver required–steering wheel optional–everyone can be a passenger in an L5 vehicle
VEHICLE	Responds only to inputs from the driver, but can provide warnings about the environment	Can provide basic help, such as automatic emergency braking or lane keep support	Can automatically steer, accelerate, and brake in limited situations	Can take full control over steering, acceleration, and braking under certain conditions	Can assume all driving tasks under nearly all conditions without any driver attention	In charge of all the driving and can operate in all environments without need for human intervention

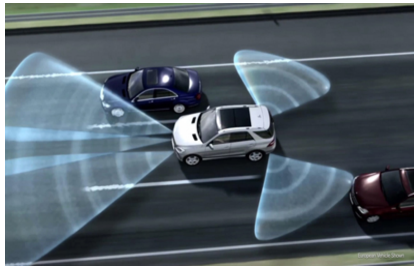
Automotive: increased functionality due to increased autonomy

Improvements on Sophisticated Automotive Advanced Drivers Assistance Systems (ADAS) like:



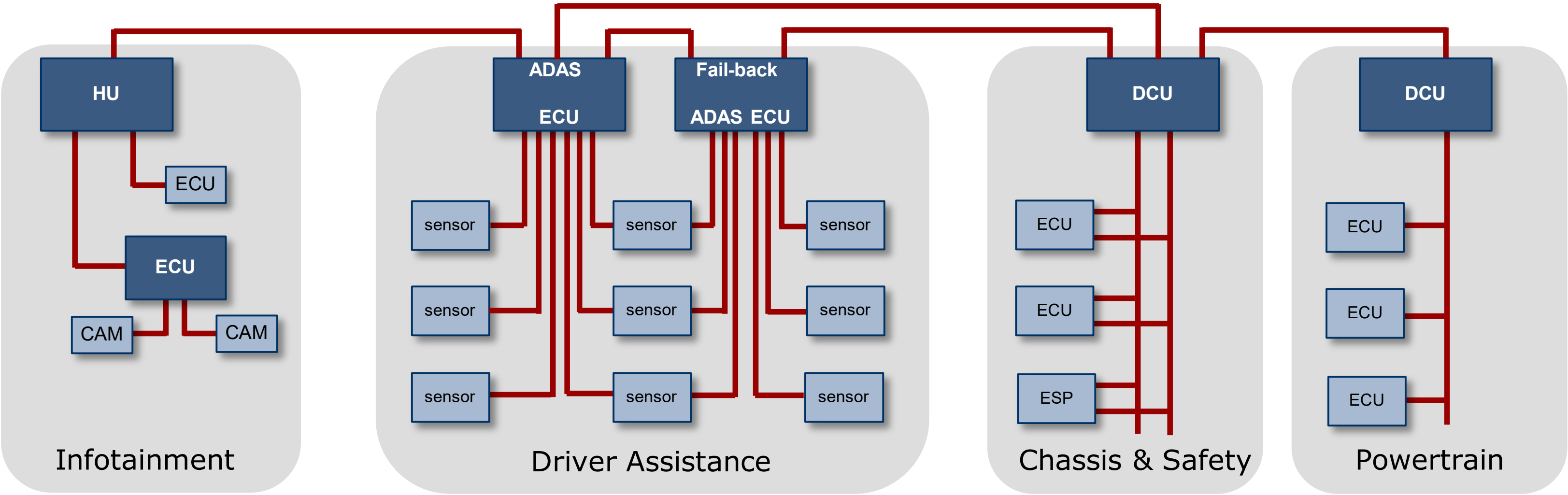
Adaptive Cruise Control

Lane Departure Assist

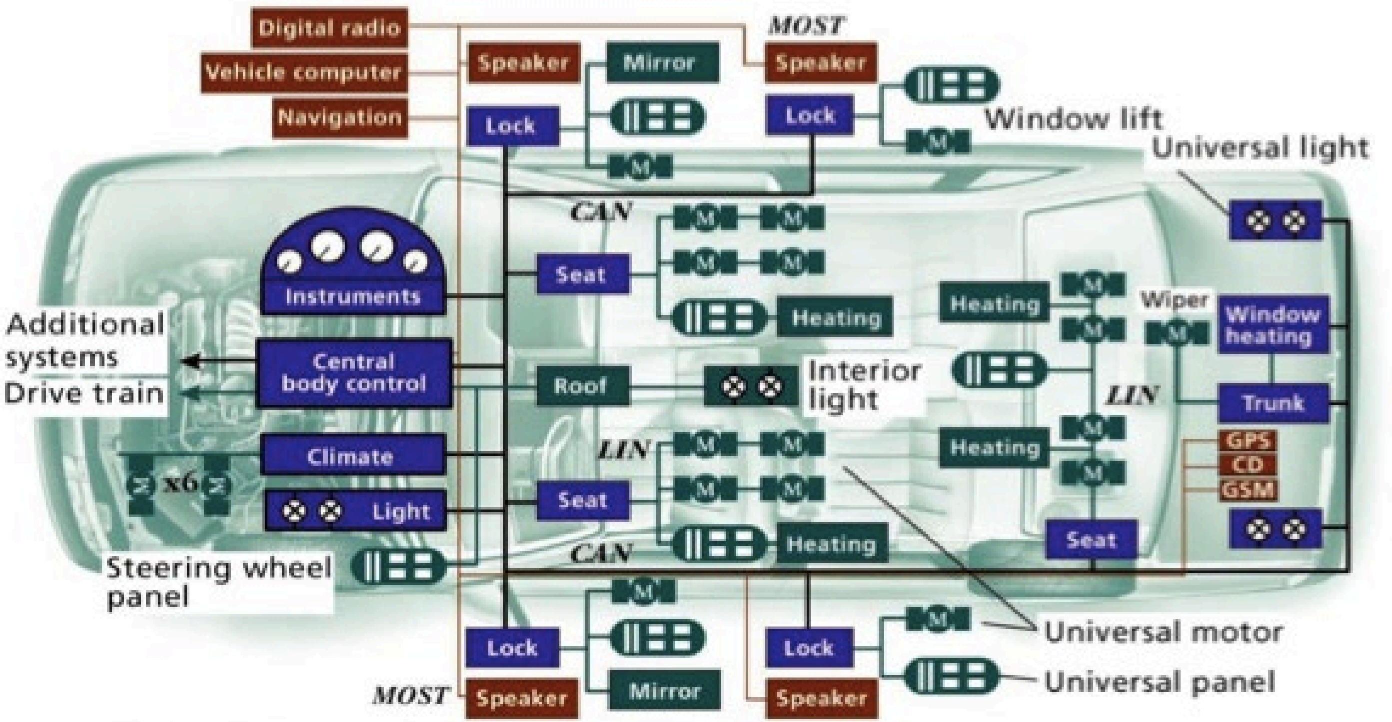


Blind Spot Assist

Brake Assist



Present: Automotive electronic systems



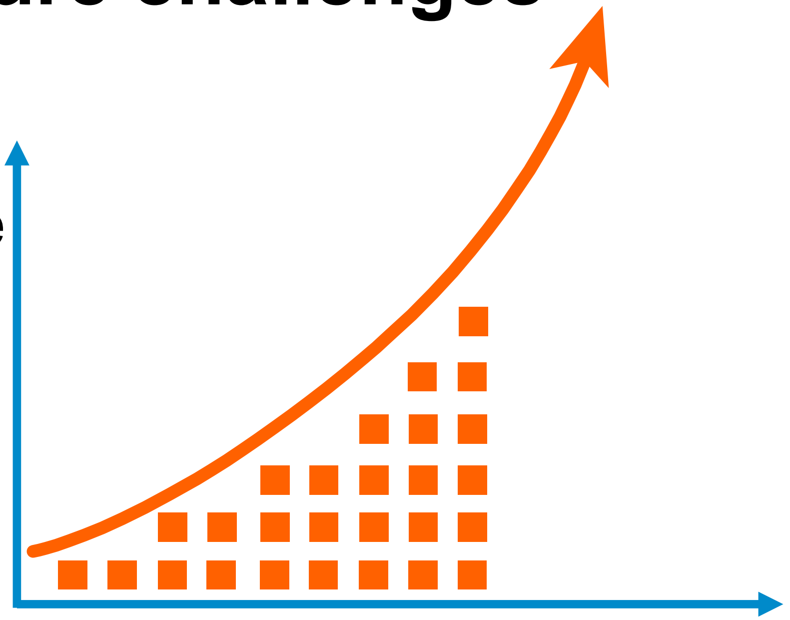
CAN Controller area network
GPS Global Positioning System
GSM Global System for Mobile Communications
LIN Local interconnect network
MOST Media-oriented systems transport

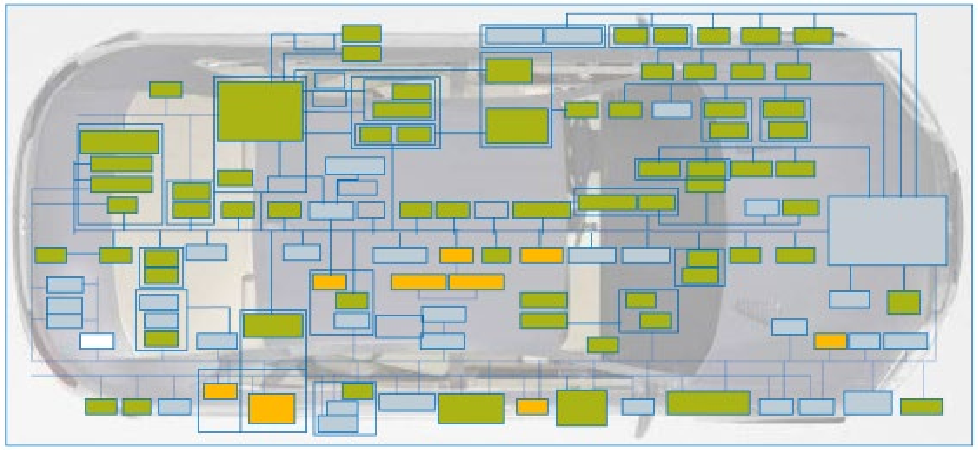
Over 100 ECUs, interconnected in several networks

ECU—Electronic Control Unit (processor, memory, communication card)

Autonomous vehicles architecture challenges

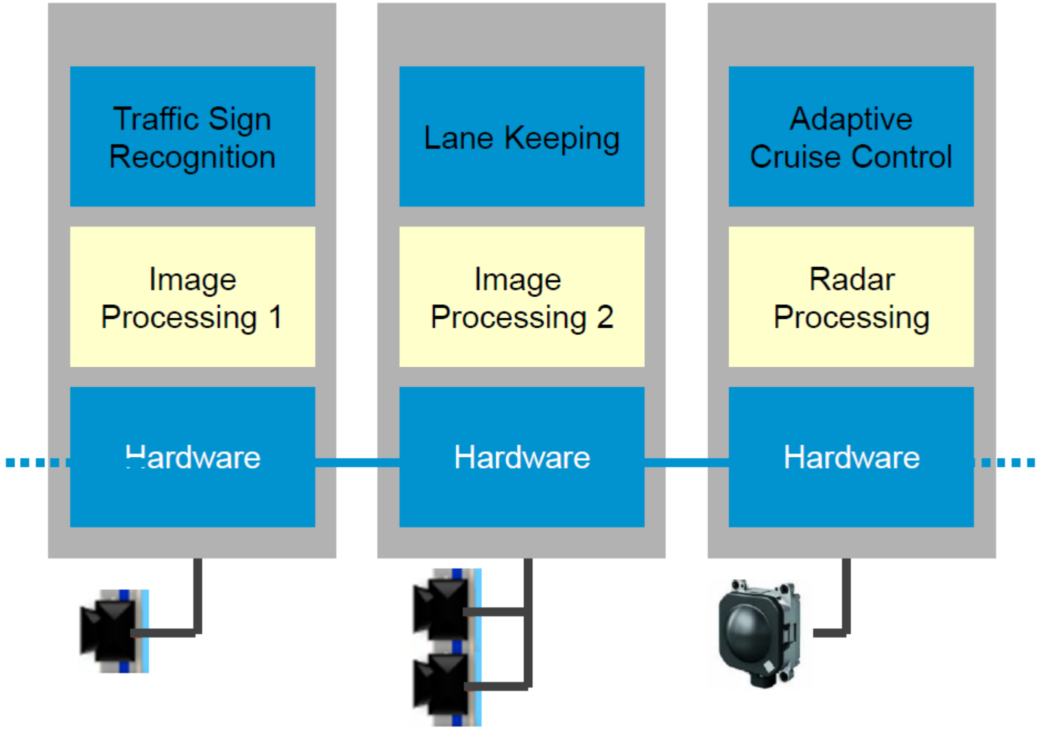
- Rapid growth of software functionality and the necessary compute performance cannot be addressed with current electronics architecture and ECUs
  - autonomous driving
  - connectivity
  - infotainment
  - electrification & hybrids
  - new mobility

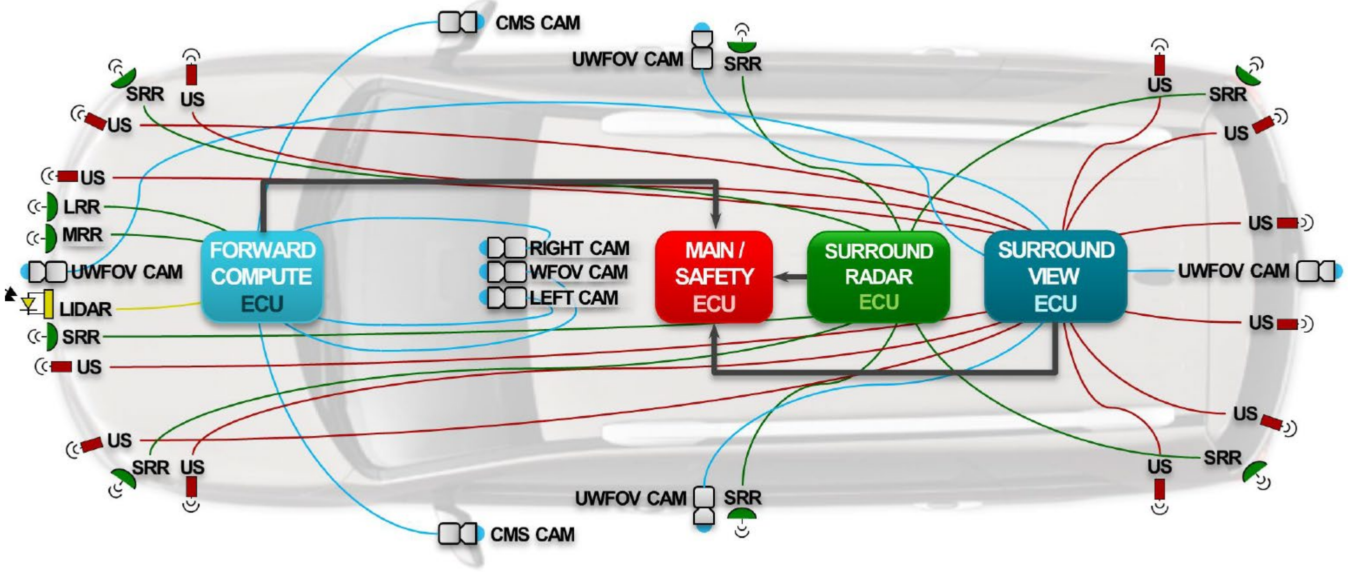




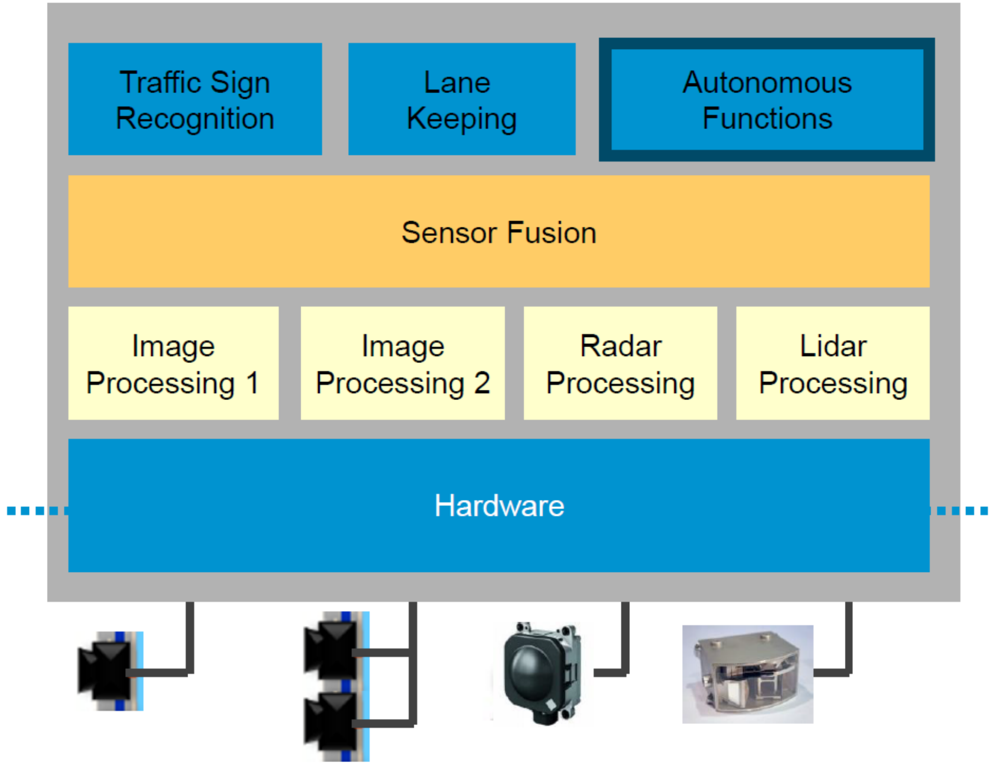
- Too many ECU's with too little processing power and memory

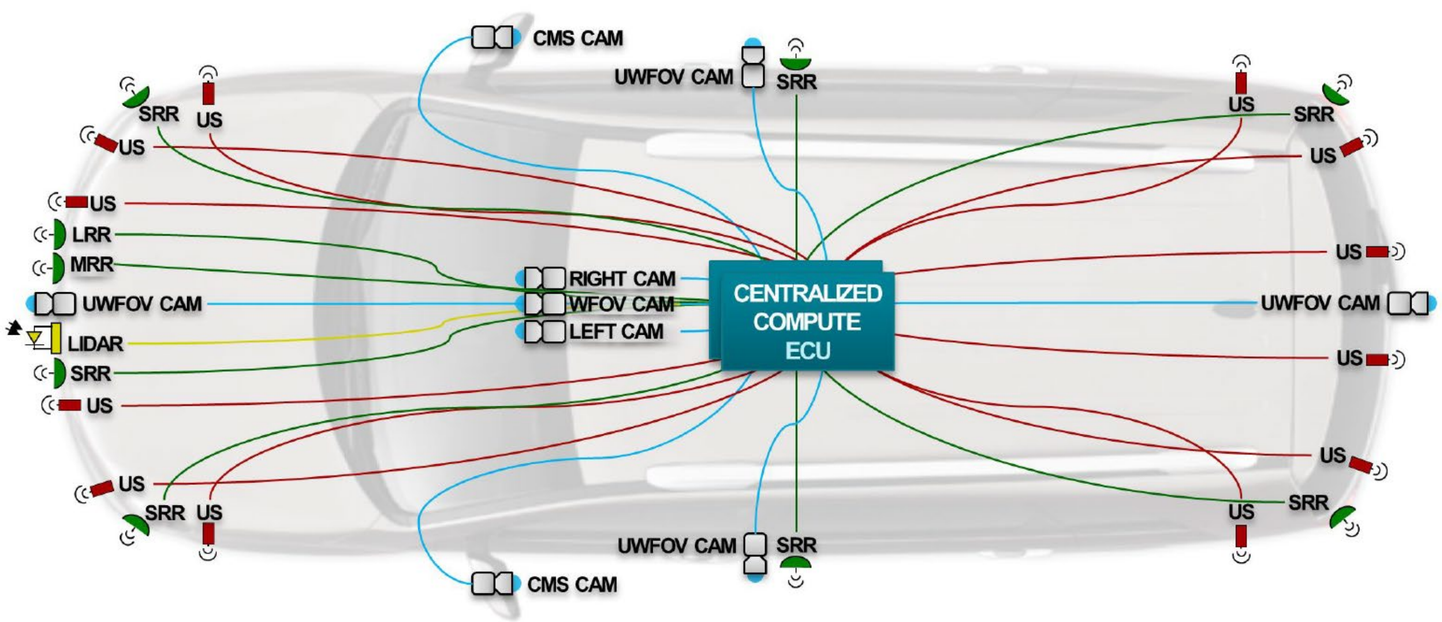
From distributed, separate ECUs …





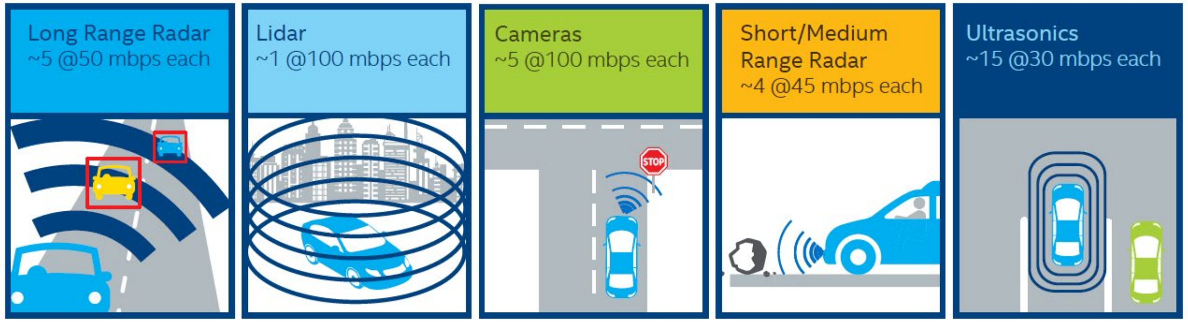
… to more integration

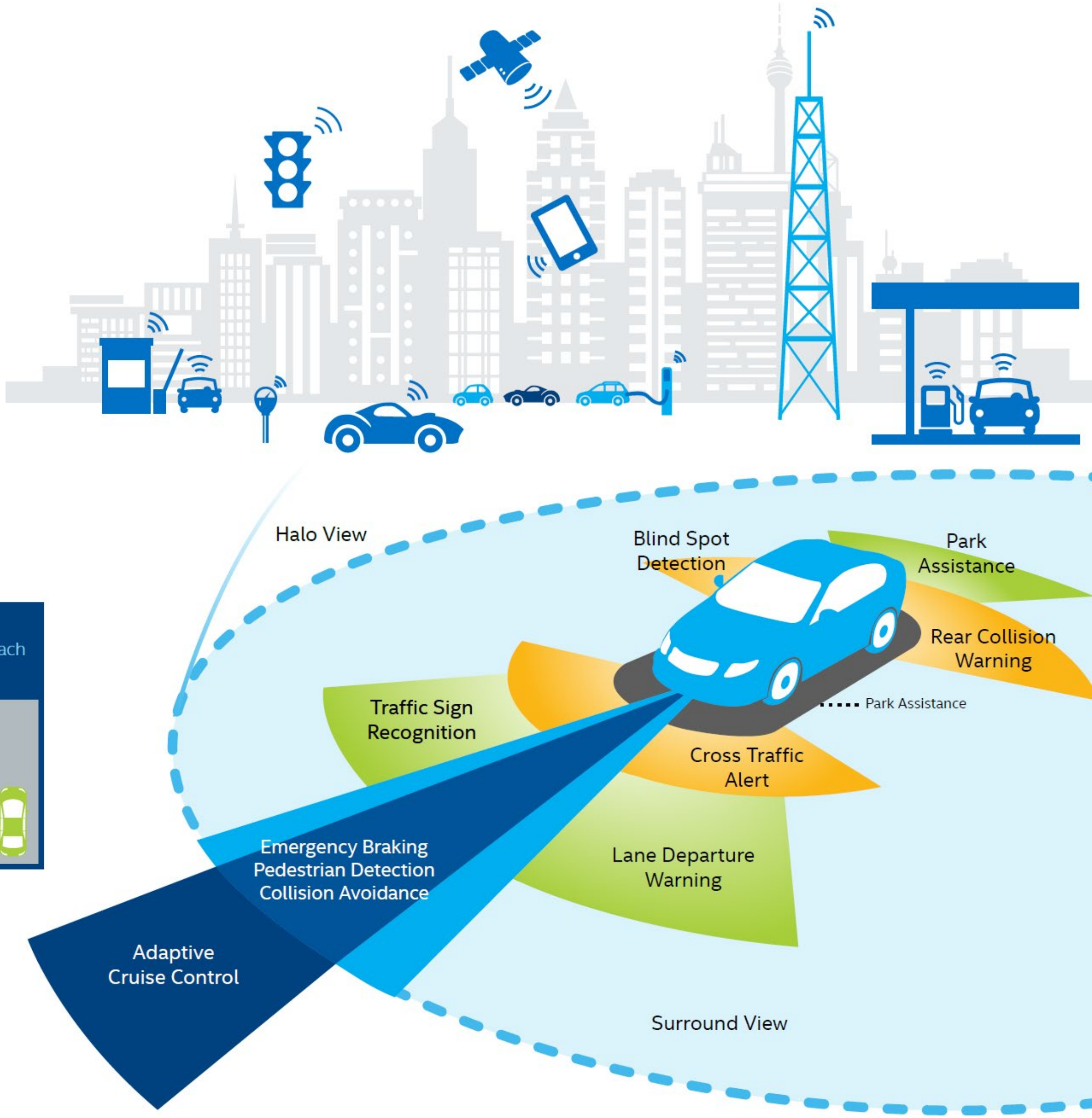




ADAS

Example sensors needed for ADAS applications





Sensors deployed today

Environment camera

Ultrasound sensors

Stereo camera

Laser scanner

Lidar

Radar

Front camera

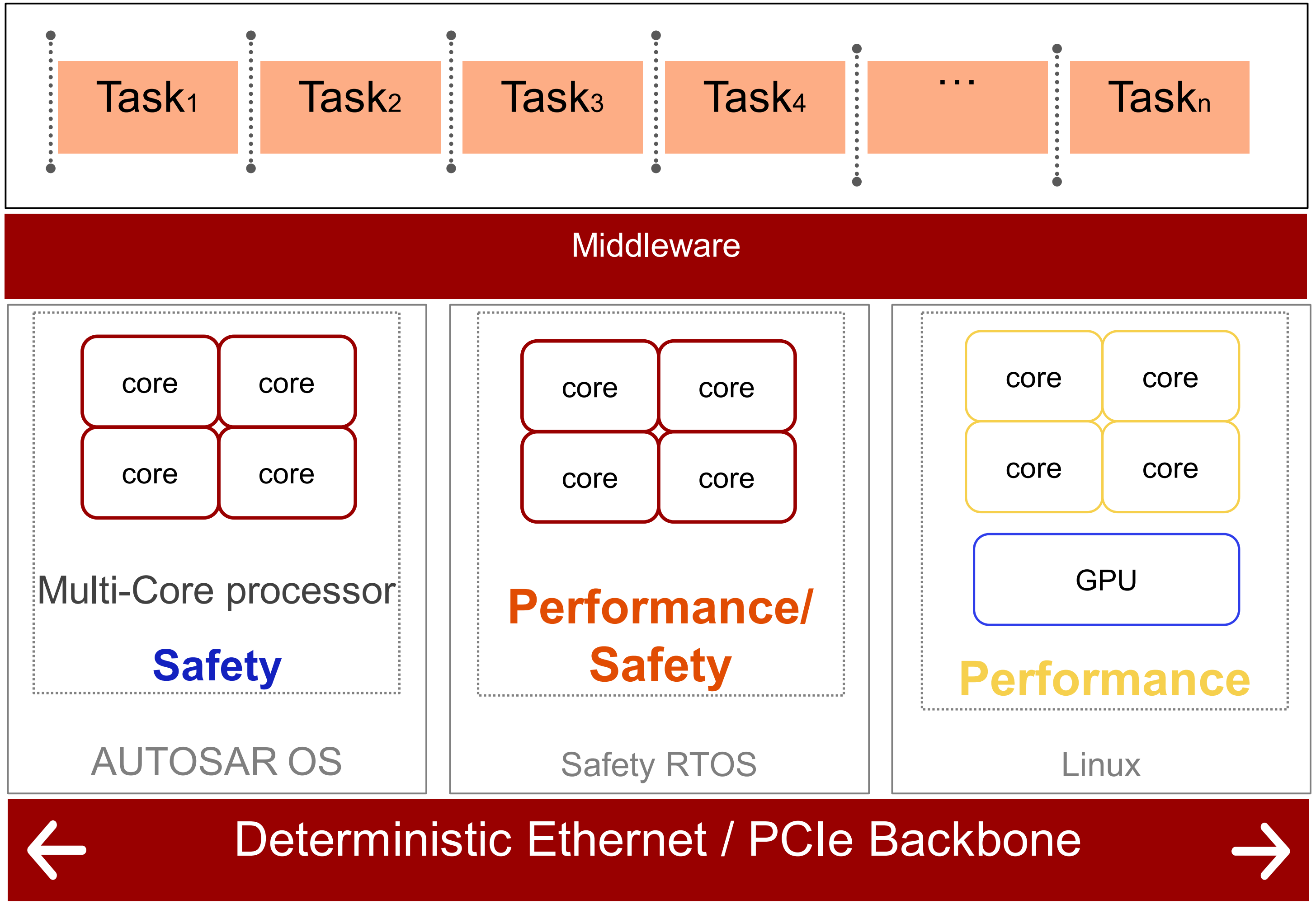
Example hardware platform: RazorMotion

Processing Resources:
1x Renesas RH850P/1H-C (ASIL D MCU
with lockstep cores @ 240MHz)
2x Renesas R-Car H3 (ASIL B SoC with 4x Cortex A57, 4x
Cortex A53, 1x Cortex R7, 1x IMP-X5, 1x IMG GX6650 GPU)

Video Interfaces:
12 x camera inputs (GMSL) incl. remote supply (PoC) 2 x
display outputs (FPD-Link III)

Communication Interfaces:
4x OABR 100BASE-T1 2 x FlexRay (A/B channel) – wakeup
capable 2 x HS-CAN – wakeup capable 4 x CAN-FD 2 x LIN
I/O Interfaces 2 x analog/digital inputs 2 x high side outputs
1 x sensor supply output (5V)

Example software platform: MotionWise



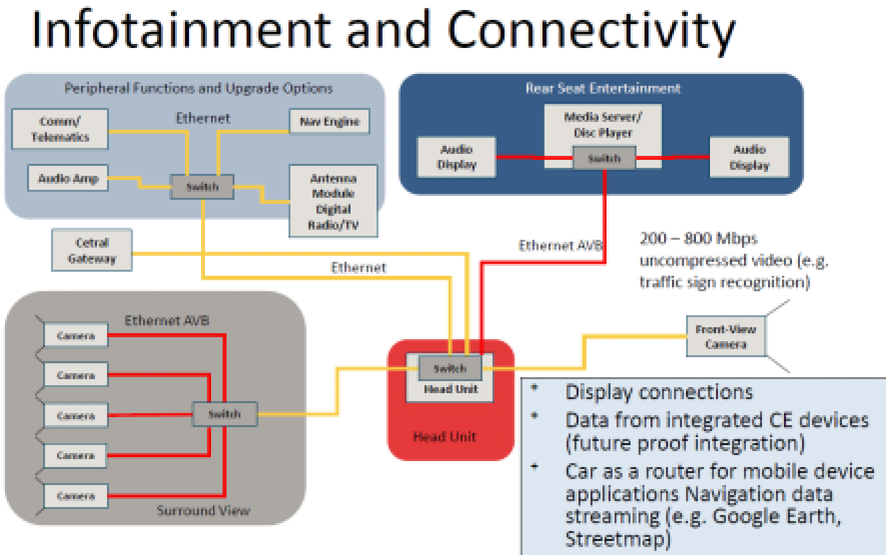
Heterogeneous multicore multi-System-on-Chip (SoC) platform featuring a variety of CPUs and GPUs running at different speeds

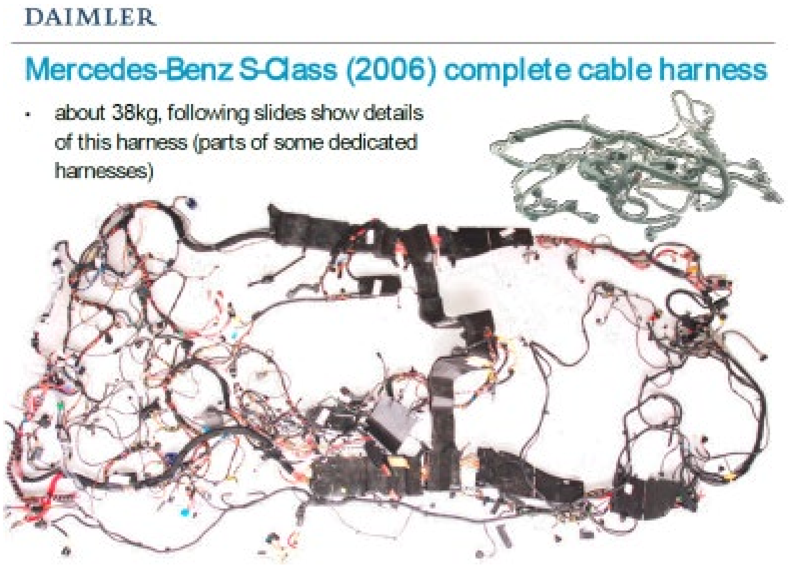
Interconnected through either a deterministic Ethernet backbone (TSN) or through PCIe

Using a variety of operating systems, depending on the criticality, a safety-critical middleware

Evolution of vehicular networks

- Why use networks in vehicles
  - Reduced Wiring Harness → Reduced weight and cabling costs
  - Reduce overall costs by using standardized chips
  - Reduce risks of binding to one silicon/solution vendor
  - Unified solution for different application areas (e.g. Infotainment, Power Train, Driver Assistance, …)





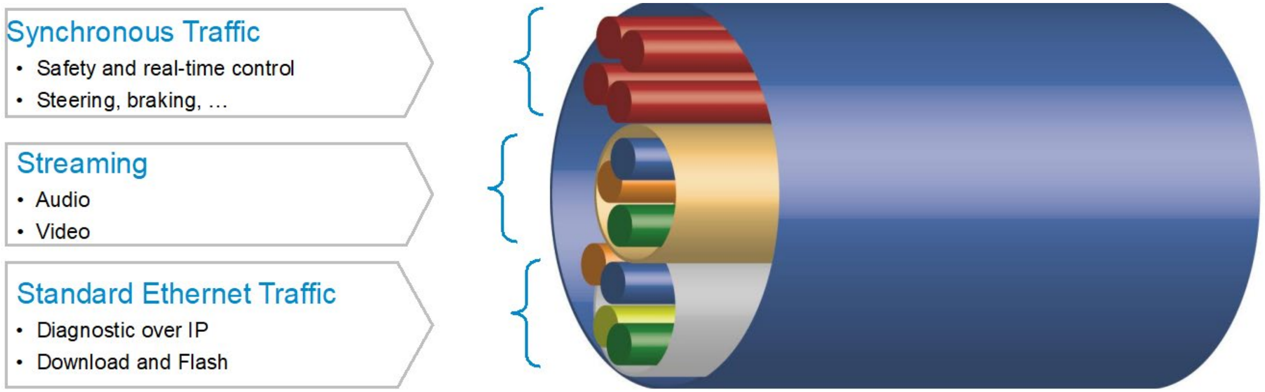
Picture Sources: IEEE 802.3 RTPGE SG

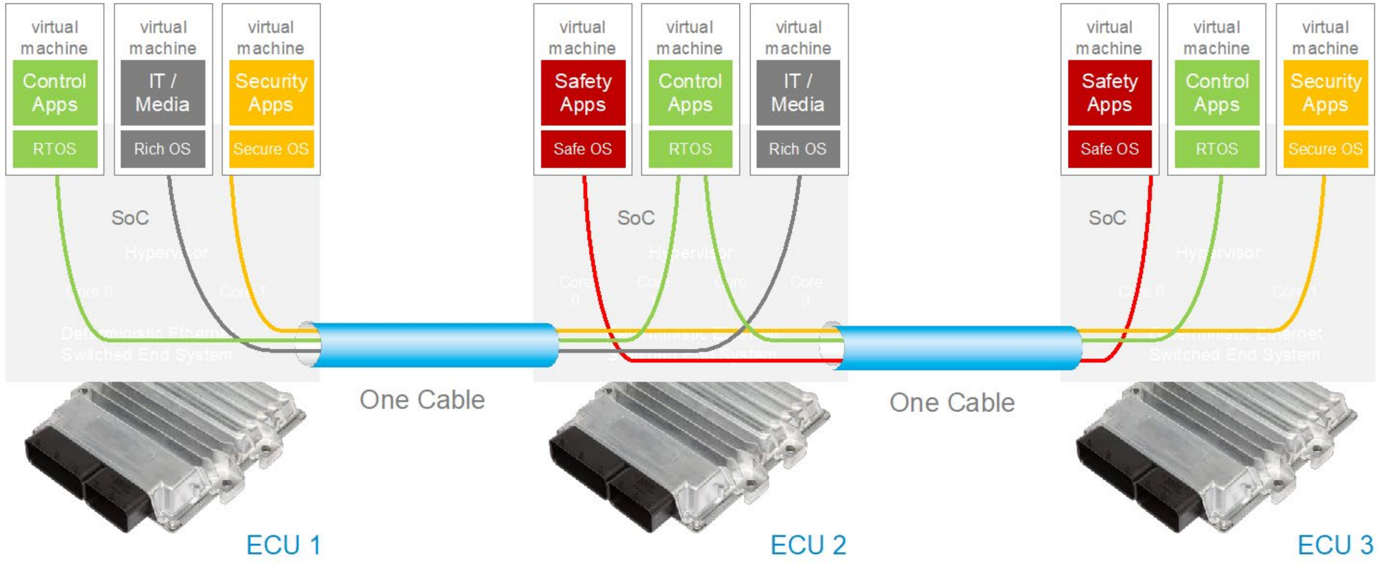
Network convergence: IEEE Time-Sensitive Networking

Principles **Integration**

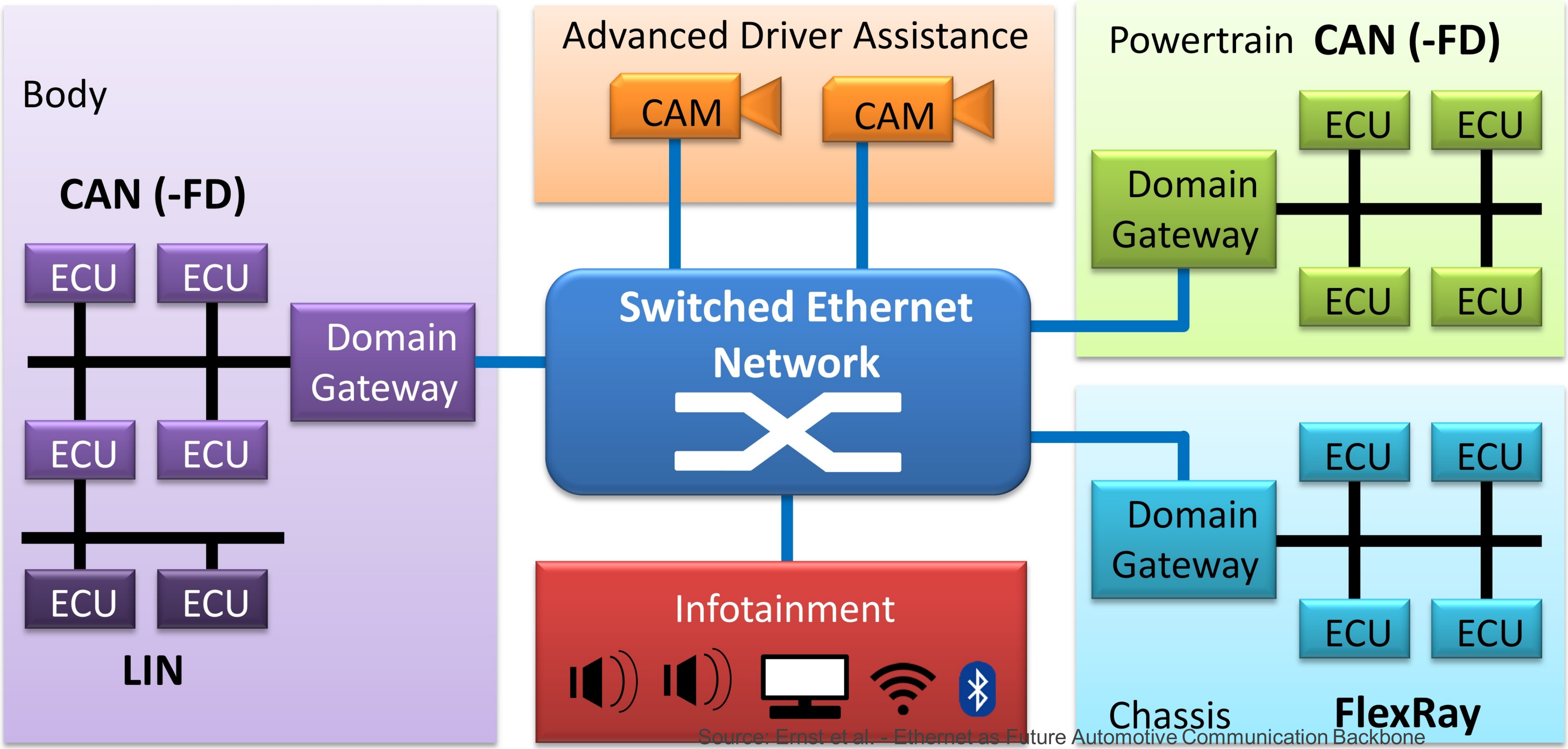
Multiple traffic classes share the network, supporting applications with mixed-criticality requirements

Separation: Virtual links separate different criticalities



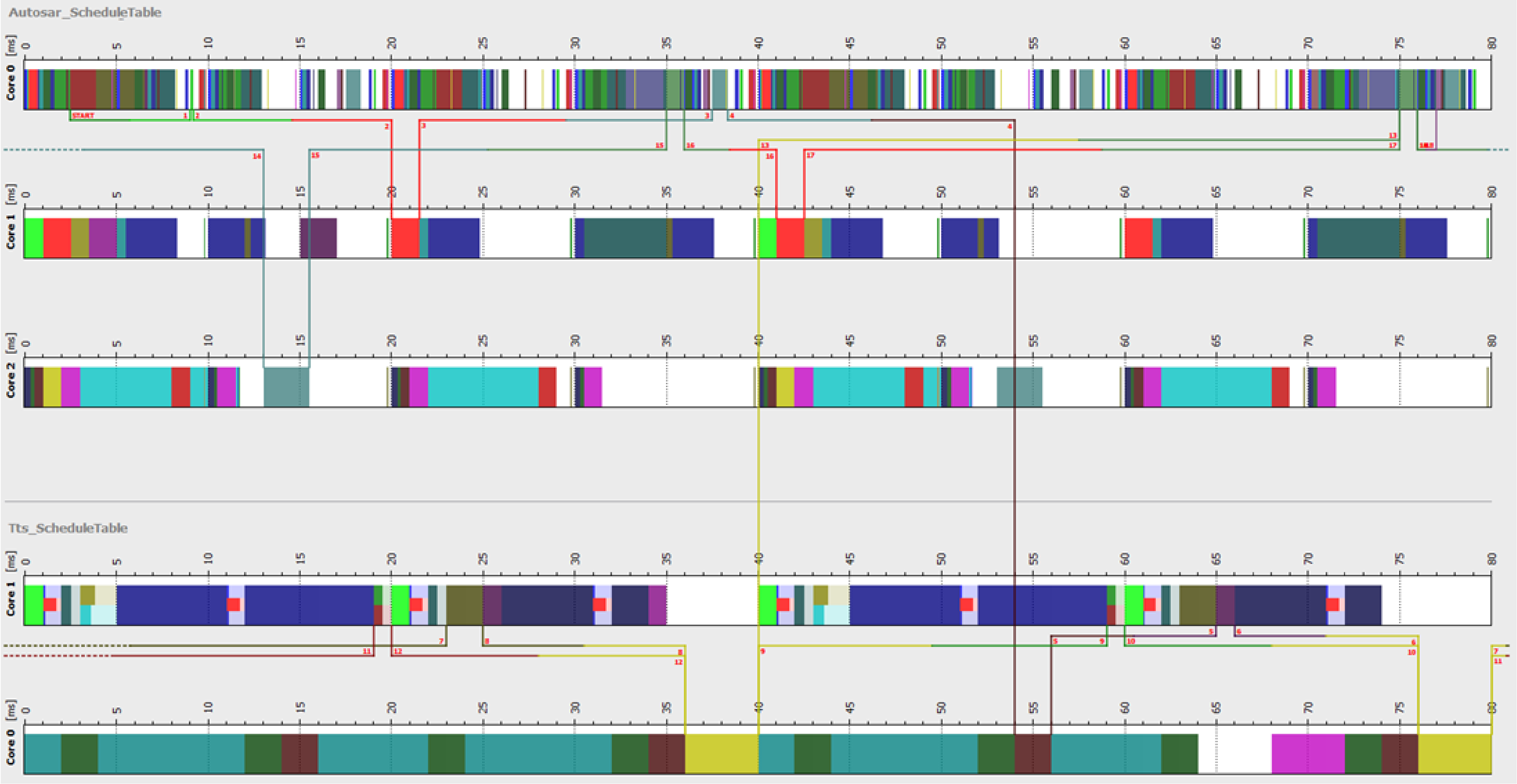


Switched Deterministic Ethernet (TSN) in Automotive



Source: Ernst et al. - Ethernet as Future Automotive Communication Backbone

Configuration challenge: mapping & scheduling



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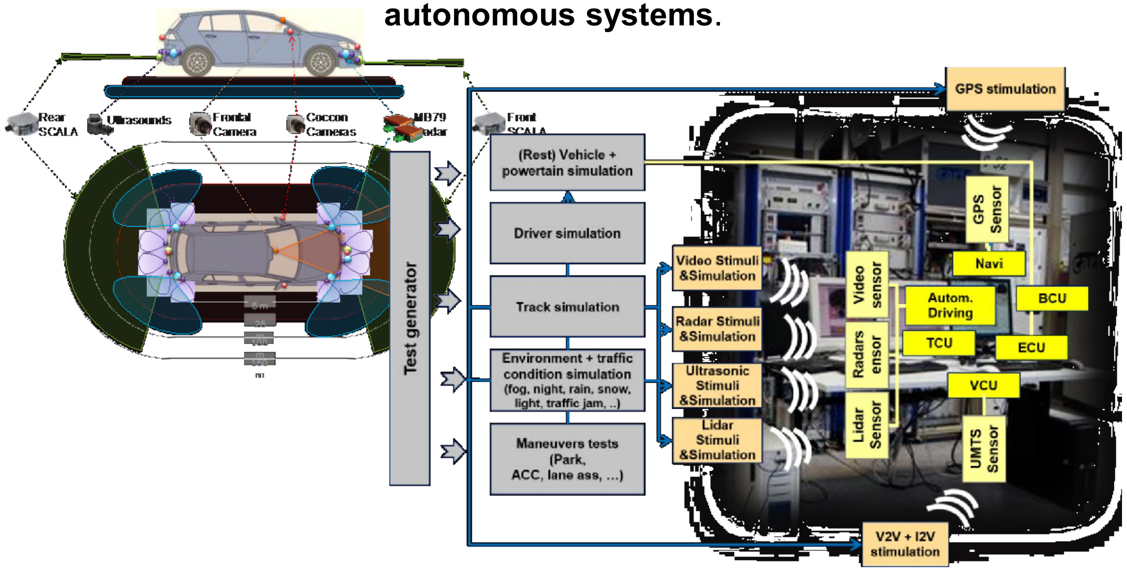
Mapping and Scheduling Automotive Applications on ADAS Platforms using Metaheuristics

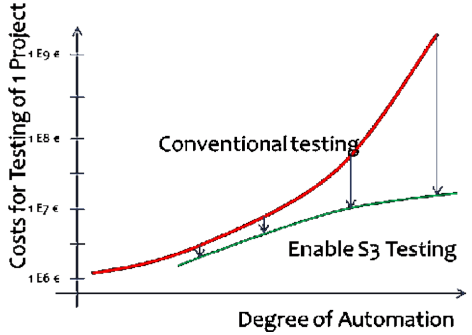
Thilo Sauter	*Francisco Vasques*	*Lucia Lo Bello*	*Valeriy Vyatkin*
General Co-Chair	*General Co-Chair*	*Program Co-Chair*	*Program Co-Chair*

ENABLE-S3—EU ECSEL, 2016-2019, 143 M€, 74 partners

European Initiative to Enable Validation for Highly Automated Safe and Secure Systems

Objectives Substitute today's cost-intensive validation and verification efforts by **virtual and semi-virtual testing and verification**, coverage-oriented test selection methods and **standardization** for efficient development of **highly automated** and **autonomous systems**.





Danish focus: **automated farming**

Partners:

DTU
Runtime validation, analysis and config. of communication

NABTO (SME)

Sky-Watch (SME)

Aalborg University

Builds on **GUARD** EU ECSEL **failed proposal 2014**, 69 partners, >100 M€, WP leader, country coordinator

EMC2 EU ECSEL AIPP project, 99 partners, 100 M€, WP leader and country coordinator

SafeCOP—ECSEL 2016-2019, 28 partners, 5 countries
11 M€ EU budget, 1,300 PMs

Objectives

Safe Cooperating Cyber-Physical Systems (CO-CPS)
using Wireless Communication

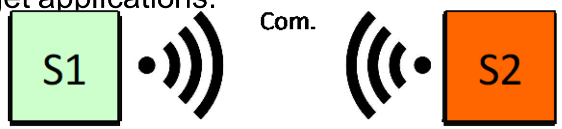
Develop a safety-assurance framework for CO-CPS.

Develop a reference platform to support the engineering and certification of CO-CPS.

Extend the current wireless protocols for safe & secure cooperation.

Contribute to new standards and regulations.

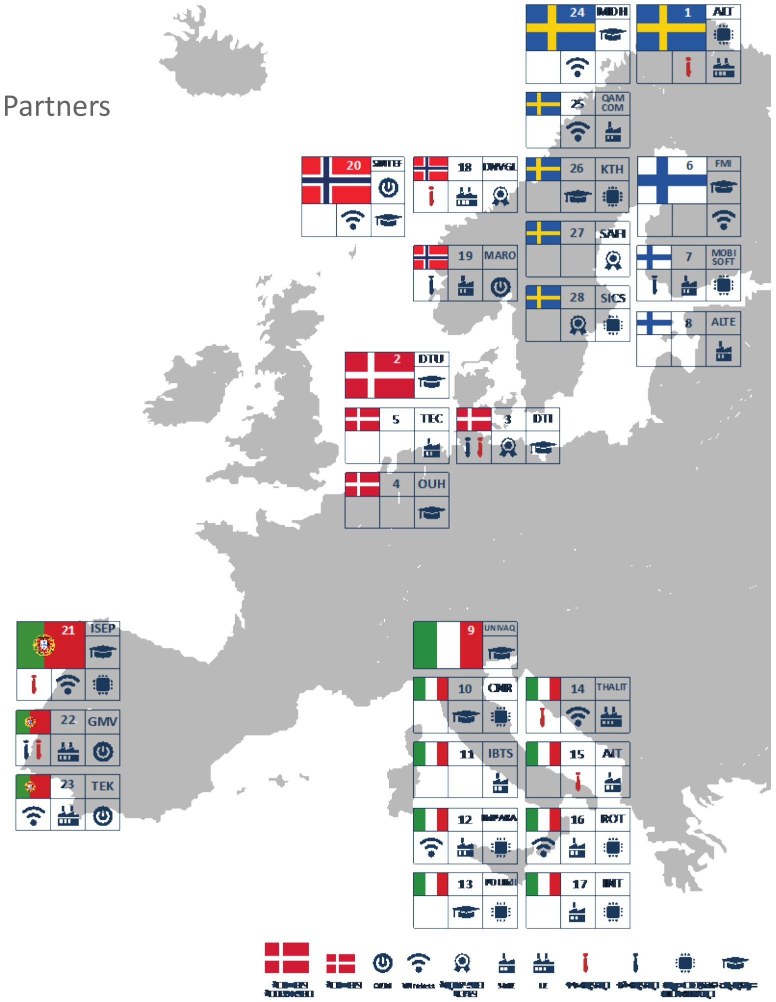
Demonstrate the usefulness of SafeCOP concepts in target applications.



Cooperative Open Cyber-Physical Systems (CO-CPS)

UC1. Cooperative moving of empty hospital beds	UC2. Cooperative bathymetry w/ boat platoons	UC3. Vehicle control loss warning	UC4. Vehicles and roadside units interaction	UC5. V2I cooperation for traffic management

Partners



Builds on **EMC2** ECSEL AIPP project, 99 partners, 100 M€, WP leader and country coordinator

RECOMP EU ARTEMIS, 41 partners from 9 countries, WP leader and country coordinator

National project: AgroRobottiFleet

DTU: dependable wireless communication