Dependable microcontroller architectures – challenges and opportunities in a fast-changing automotive market

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Infineon Headquarter, Neubiberg

Infineon at a glance

Growth areas

Energy
green and efficient

Mobility
clean and safe

IoT
smart and secure

Market Position & Share

#1 Automotive Microcontroller

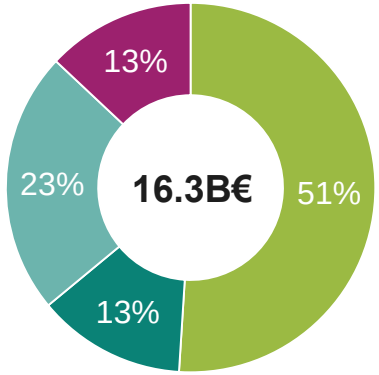
#1 Automotive Power Semiconductors

#2 Automotive Sensors

TechInsights: *Automotive Semiconductor Vendor Market Shares*. March 2024. Sensors: S&P Global: *Automotive Semiconductor Market Share Database*. April 2024.

FY23 revenue by segment[1]

- Automotive (ATV)
- Green Industrial Power (GIP)
- Power & Sensor Systems (PSS)
- Connected Secure Systems (CSS)

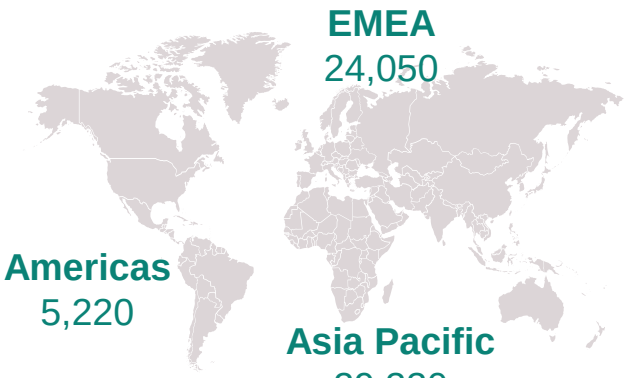


Employees[1]

58,600
employees worldwide

69
R&D and

15
manufacturing locations[2]



For further information: Infineon Annual Report.
1 2023 Fiscal year (as of 30 September 2023) | **2** As of 1 August 2024

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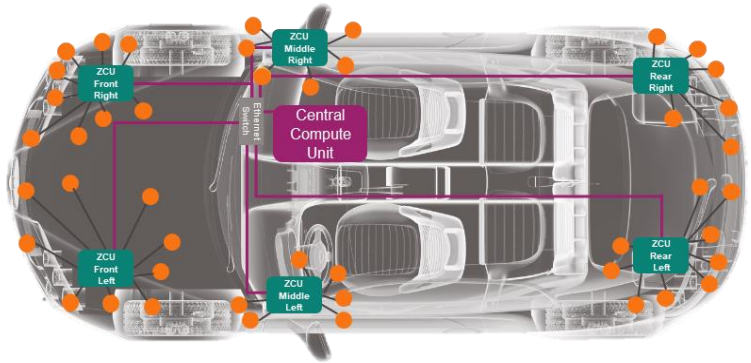
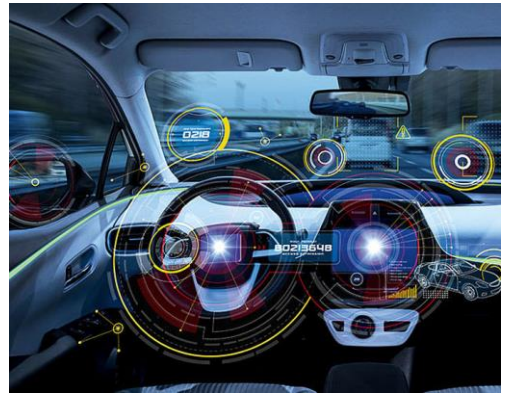
Automotive Megatrends & Microcontroller Innovation
SDV hype is turning – full focus on cost and complexity reduction

Software Defined Vehicle

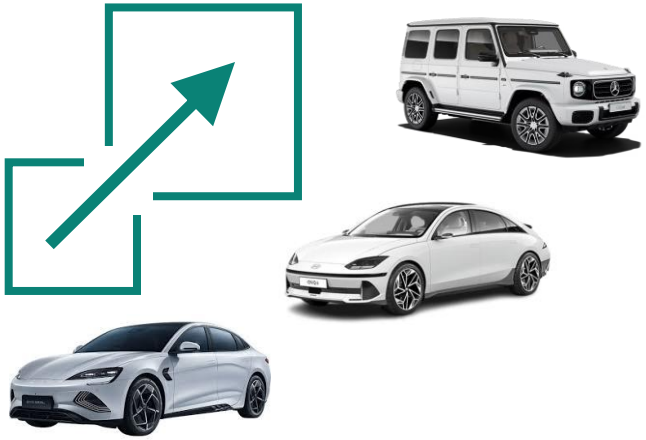
- **Software determined E/E architecture**
- **Zone ECUs** require scalability & cost efficiency
- **User experience** differentiates OEMs
- **AI enters infotainment** solutions





Vehicle Electrification

- **Electrified drivetrain** integration
- **Hybrid solutions** gain momentum
- **Battery innovation** is a key market driver
- **X-by-wire technology**



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Automotive Megatrends & Microcontroller Innovation
Security becomes a critical factor, AI technologies emerge

Cyber-security Post-quantum technology

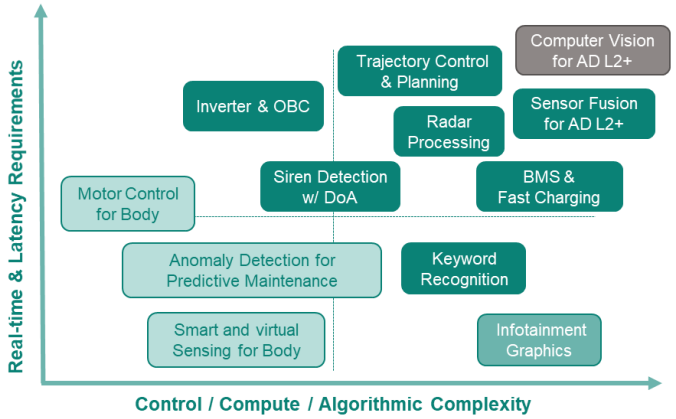
- **Quantum computers emerge**
- **Increased vulnerability** of current cryptographic systems such as RSA and ECC
- **New security accelerator technology** needed

“Breakpoint for current microcontroller unit platform are security capabilities”
– T1 customer –

“Security can kill a microcontroller unit platform, because it doesn’t scale” – OEM –

Safe Embedded AI technology

- **AI based control**
- **Local data processing** on the device
- **Faster response times** & improved data security
- Cost Savings



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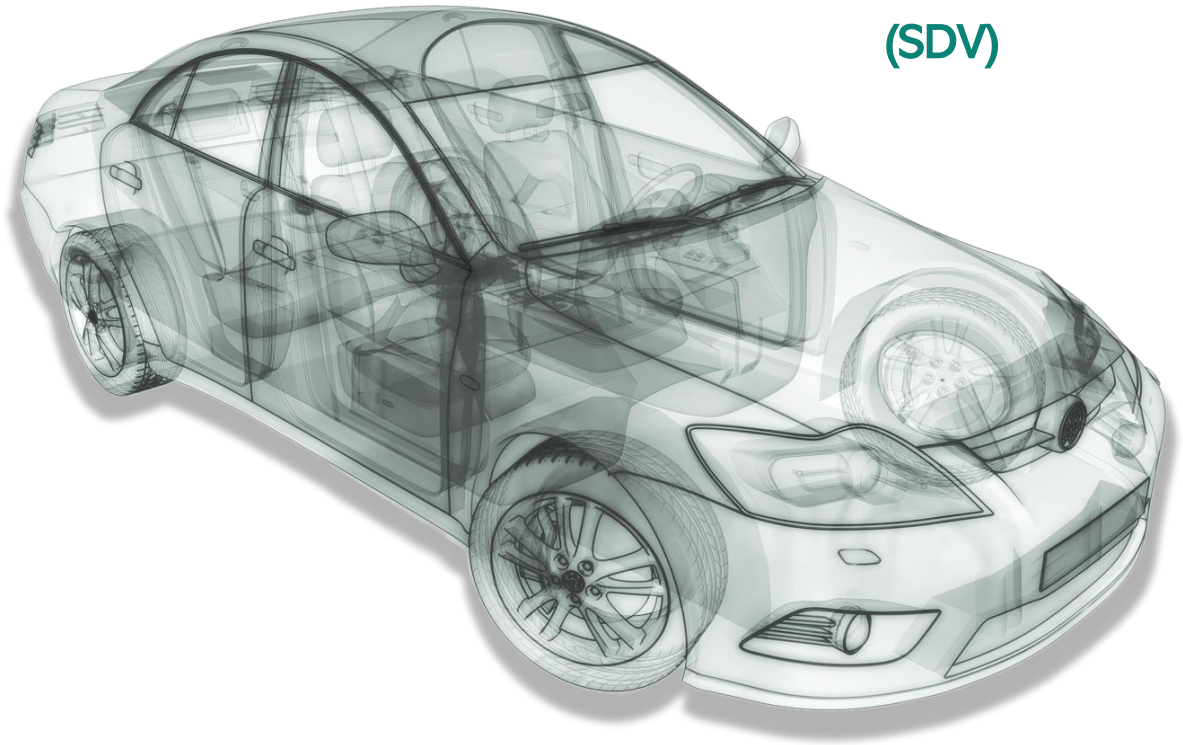
Software Defined Vehicle (SDV)

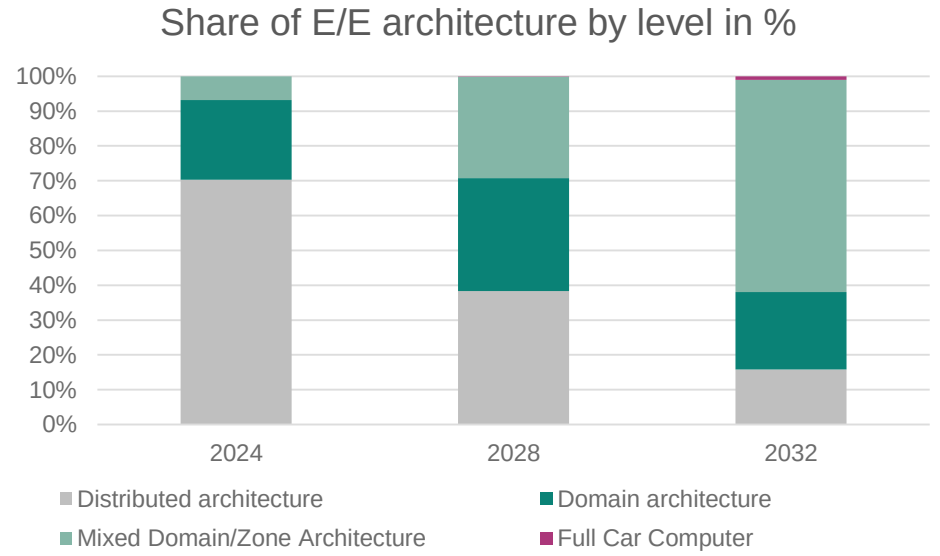


Major innovations are software driven

Number of vehicle Electronic Control Units (ECU) is reducing

Automotive industry design cycles are shortening

Huge market potential, but …



no new architecture standards yet.

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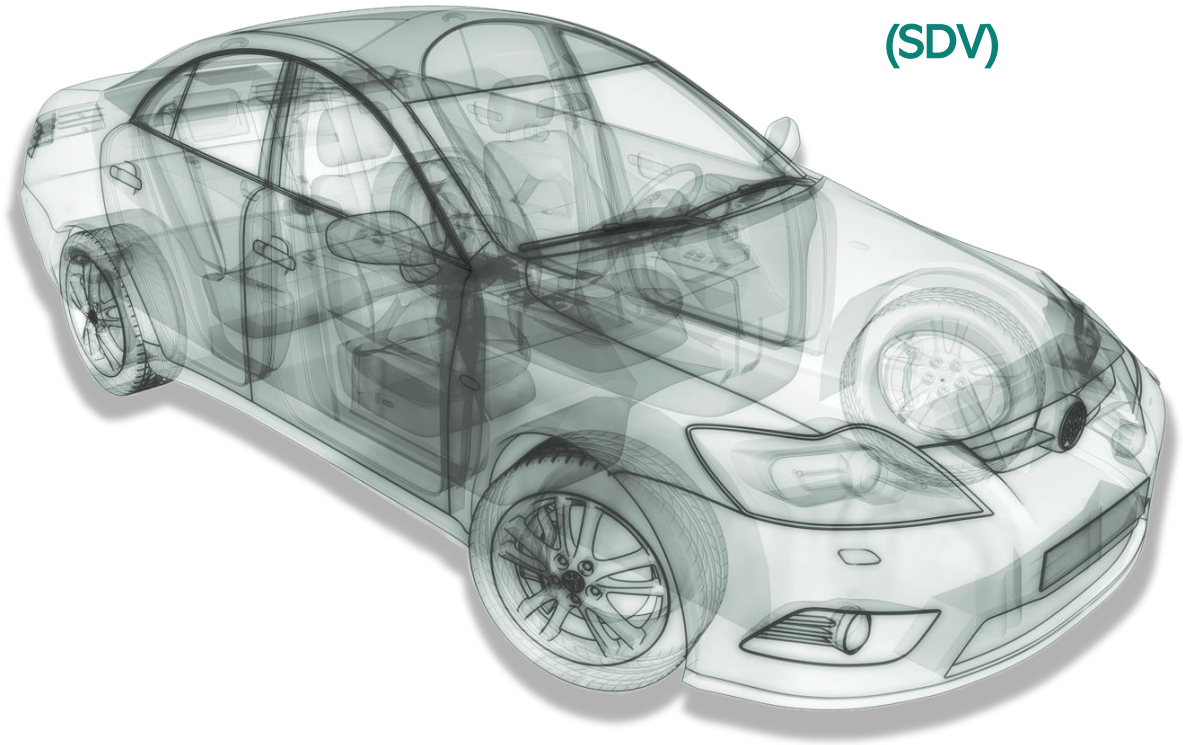
Software Defined Vehicle (SDV)



Major innovations are software driven

Number of vehicle Electronic Control Units (ECU) is reducing

Automotive industry design cycles are shortening

Microcontrollers innovation runs out of steam, no more new products, no more disruption?

Wait a minute …

Here’s how open-source technologies can enable affordable and dependable car architectures

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Performance, Cost & Dependability: Microcontroller architectures have undergone major innovations in the last 25 years

Performance

- **2000**: 8 & 16bit is standard, 32bit gains share in >2005
- **2008-2010**: Memory integration & 16bit instructions introduced

2000

- **2008-2010:** Real-time capabilities: interrupt latency minimized & fast context switching
- **2008-2010:** Safety: Memory protection

Security & Safety

- **2010-2015:** Security extension added: instructions, HSM module
- **2015-2020:** Safety becomes a standard: ISO26262

2010

- **2015-2020:** Performance: Direct Non-volatile Memory (NVM) access & application-specific accelerators, e.g. radar processing

Software & AI

- **2020-2025:** Software: Virtualization, SOTA and new types of Non-volatile Memory (NVM)
- **2020-2025:** Security: CSRM security acceleration

2020

- **2020-2025:** Performance: AI acceleration
- **2020-2025:** Performance: Data routing acceleration

What is next…

Features disruption

Cost focus

Development speed

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Enabling SDV: Key innovation areas for automotive microcontroller platforms in future vehicle architectures

Performance and throughput

- Handling of **large amounts of parallel tasks and I/O** without compromising real-time performance

Determinism and low latency

Source: Vitesco, Inverter design

- **Predictable execution time** and guaranteed timing of computations
- Minimal downtime, **robust fault tolerance and fast recovery mechanisms**
- Hardware redundancy and software diversity

Reliability and availability

Safety and security

- **High diagnostic coverage**, fault detection and mitigation, mechanism to brings systems to safe state
- Secure boot, restricted access to resources and data encryption

Source: Arnold NextG, X-by-wire

Reuse and Scalability

Source: Hyundai, e-GMPP

- **Modularity and reuse of existing software** components
- Ability to adapt to software loads, memory, communication capabilities and **system target costs**

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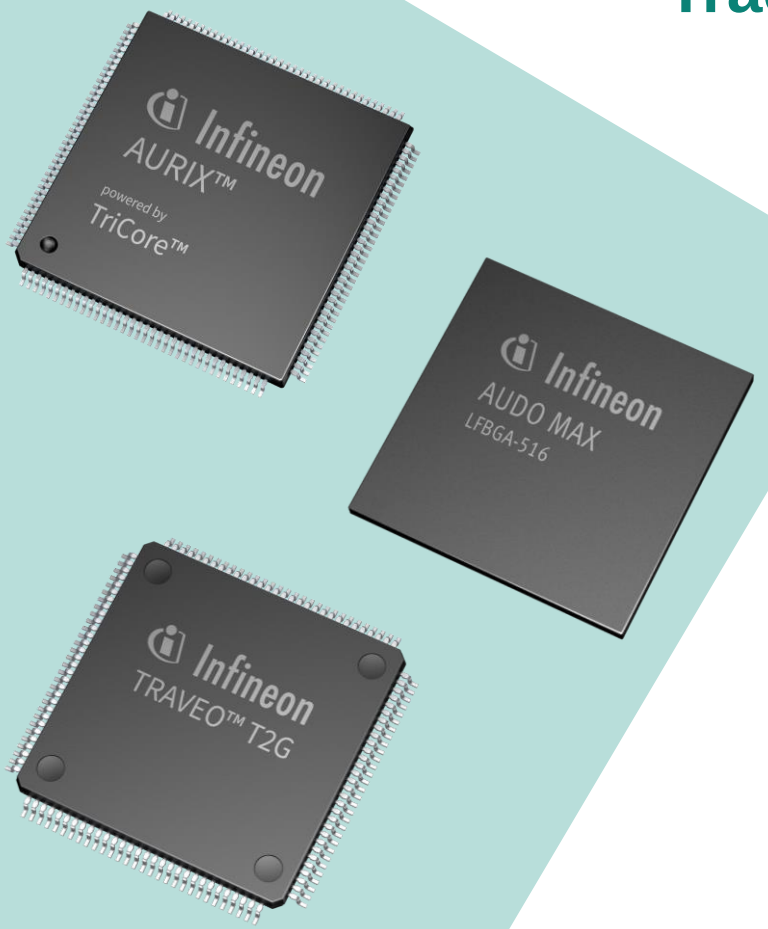
Traditionally microcontroller consisted of two building blocks using programable cores:



- **System management**
  - Reset management, clock system, memory initialization
  - Power mode handling

- **Real-time control**
  - Predictable execution time & low-latency interrupt handling
  - RTOS support incl. scheduling, task management

but complexity has evolved…

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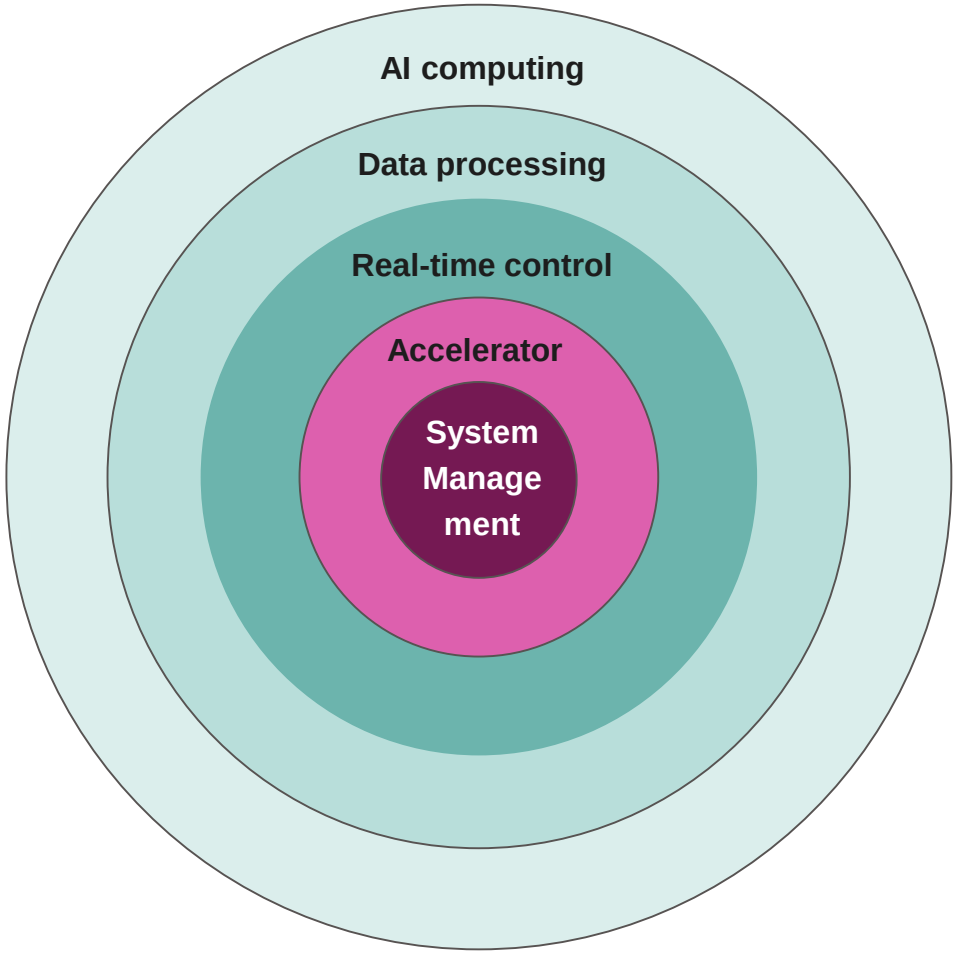
Microcontroller today: Change in automotive computational tasks requires specialization, standardization & instruction set reuse



System management
- Reset management, clock system, memory initialization
- Power mode handling

1x cores

Embedded accelerators
- Security sub-systems and accelerators
- Application-specific signal processing, Networking & protocol engines

1-4x cores

Real-time control
- Predictable execution time & low-latency interrupt handling
- RTOS support incl. scheduling, task management

1-6x cores

Data processing tasks
- High-performance handling of complex processing tasks
- Memory management support & Privileged execution modes

1-4x cores

AI inference tasks
- Specialized hardware for matrix and tensor computations
- Model compression and optimization support

1-Nx cores

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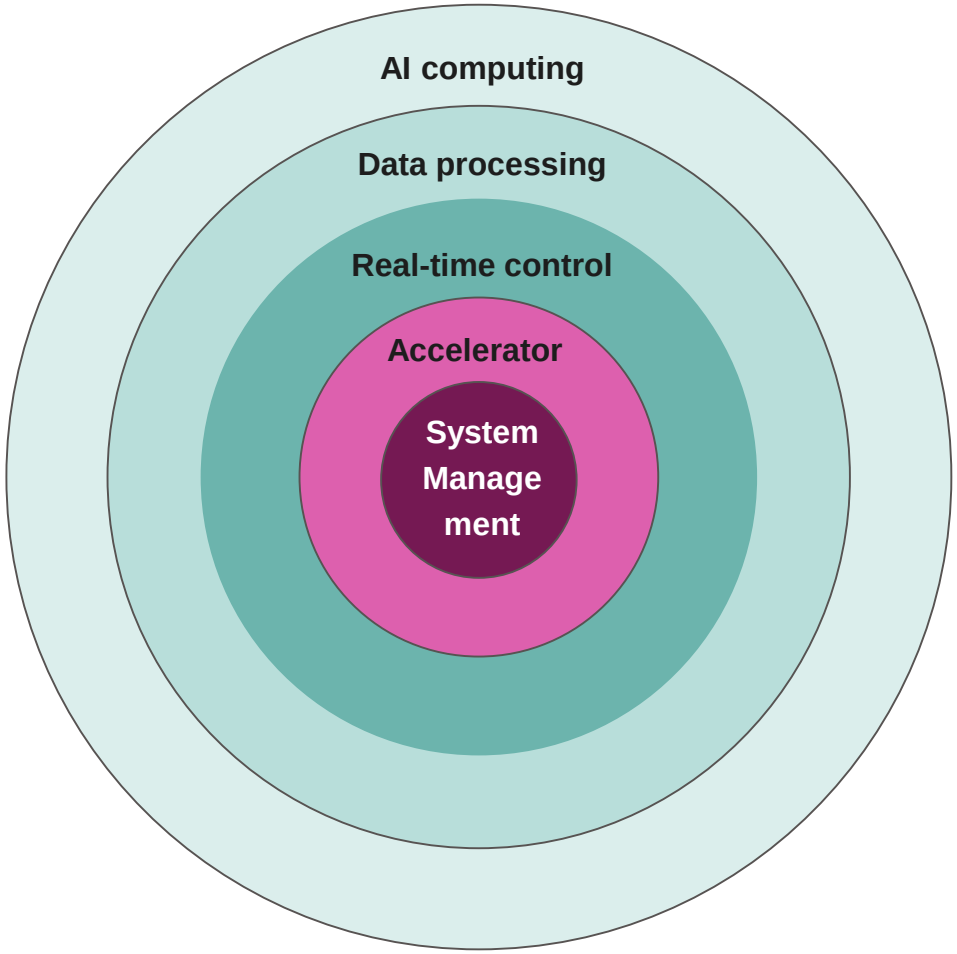
Microcontroller today: Change in automotive computational tasks requires specialization, standardization & instruction set reuse



System management — 1x cores
- Reset management, clock system, memory initialization
- Power mode handling

Embedded accelerators — 1-4x cores
- Security sub-systems and
- Application-specific signal , Netw rotocol engines

Real-time control — 1-6x cores
- Predictable execution low-la nterru dling
- RTOS support incl. sc ask manage

Data processing t — 1-4x cores
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AI inference tasks — 1-Nx cores
- Specialized hardware for matrix and tensor computations
- Model compression and optimization support

RISC-V

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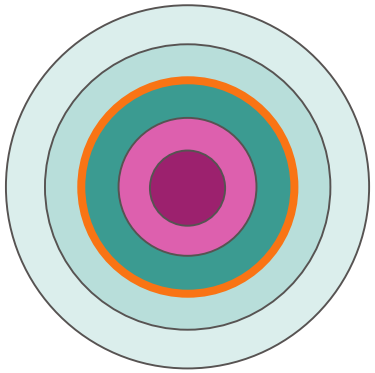
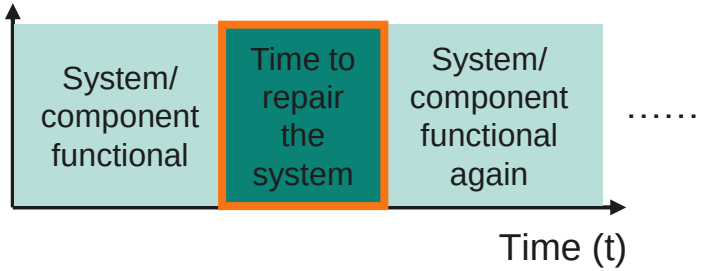
Modern core architectures address two main challenges: Dependability & Scalability

Challenge: Dependability

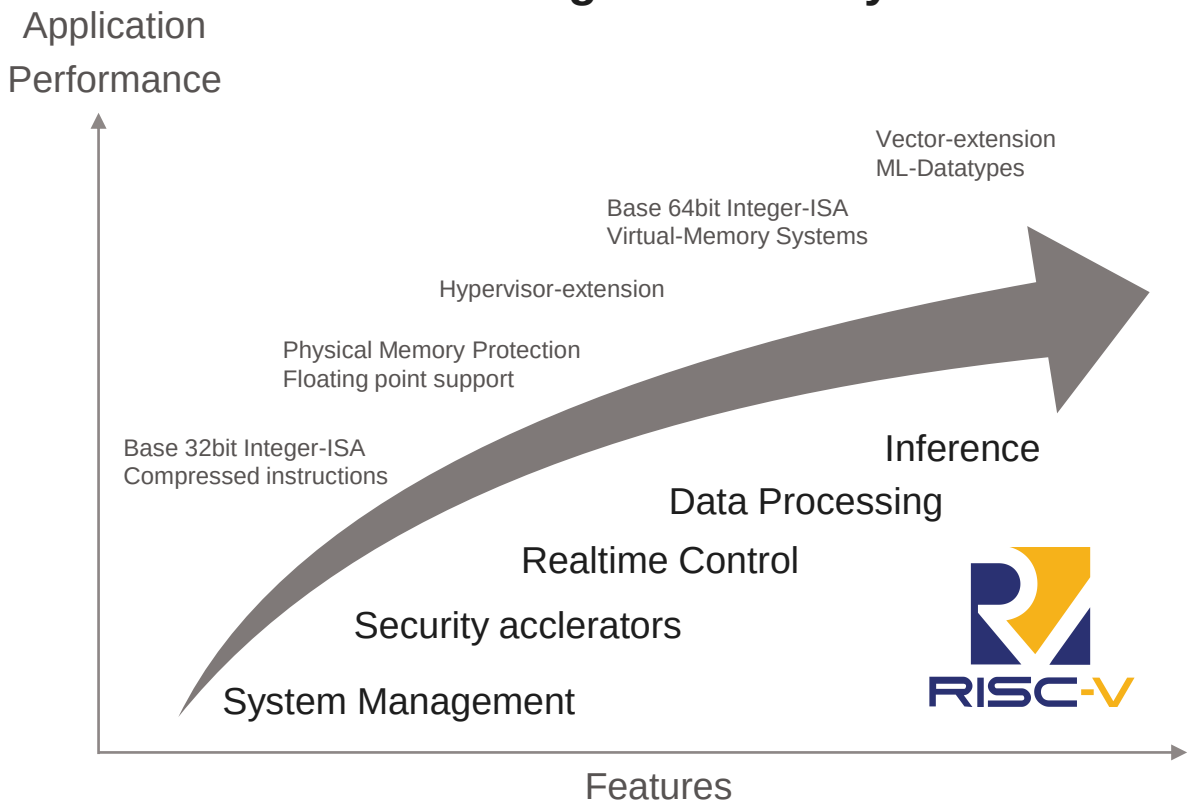
Dependability is a measure of a system's **availability, reliability, maintainability, safety and security.** The ability to maintain **functionality** when parts of a **system break down** is referred to as **graceful degradation**





Dependability and graceful degradation requires safe and scalable core portfolio

Challenge: Scalability



Core architecture needs to support extensions to support all application domains

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Note: Relevant extensions shown exemplary.


Embedded
Security

New E/E architecture is leading to increasing security requirements and enhanced security cluster demand

Why is an enhanced security cluster needed?

Minimize latency & maximize throughput for “In Vehicle Network” (IVN) communication

Secure in-vehicle networking , authentication of >50% and encryption of >15-20% of all IVN messages

Enable SOTA based on secured and safe distribution of SW updates

Increasing number of security use cases to be addressed in future car architectures

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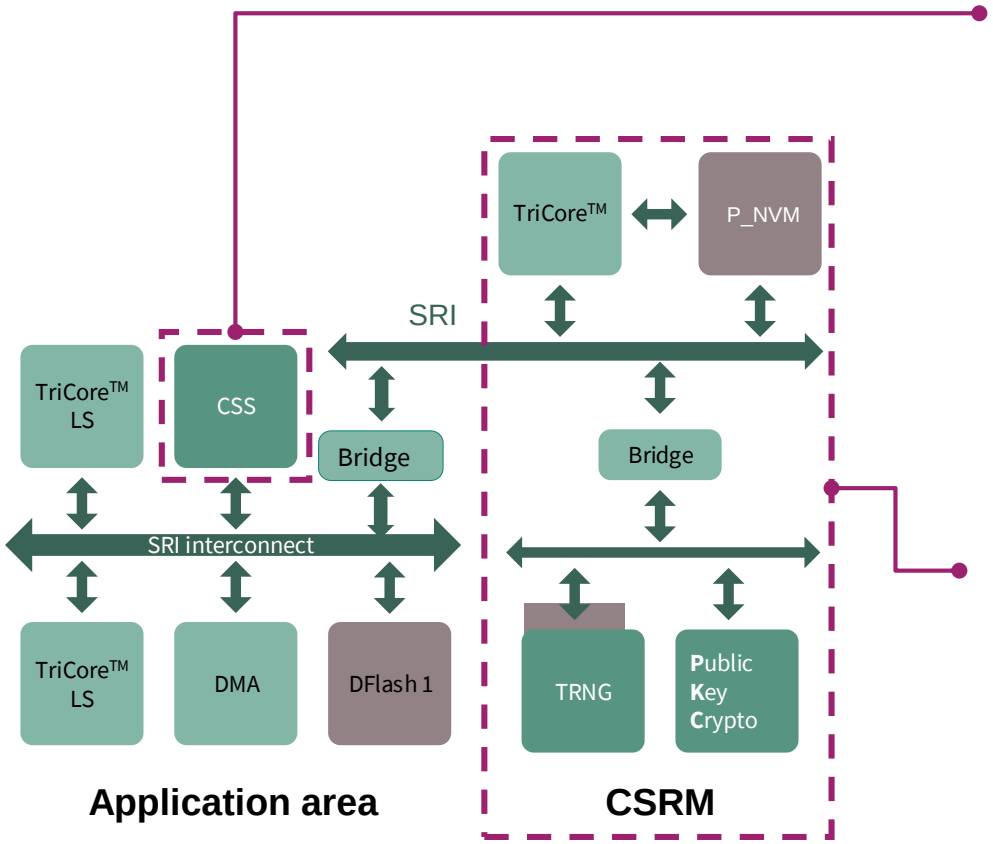
Next generation security cluster increase throughput by parallel computation and supports upcoming new security standards

New security cluster architecture



High performance security with high throughput will be a key requirement

Cyber security satellite (CSS) for parallel computation

- Parallel HW accelerators for secure communication tasks
  - Increasing throughput
  - Minimizing latency
- Up to 21 individual channels to be used in communication-rich applications, e.g. gateway use cases
- Provides freedom of interference for domain / zone controllers

Cyber security real-time module (CSRM) for performance increase

- TriCore™ 1.8 based providing ~5-15x performance vs. ARM M3
- CSRM support of latest security standards, e.g. ISO 21434
- Private memory to enable security SW updates independent of application cores and application code

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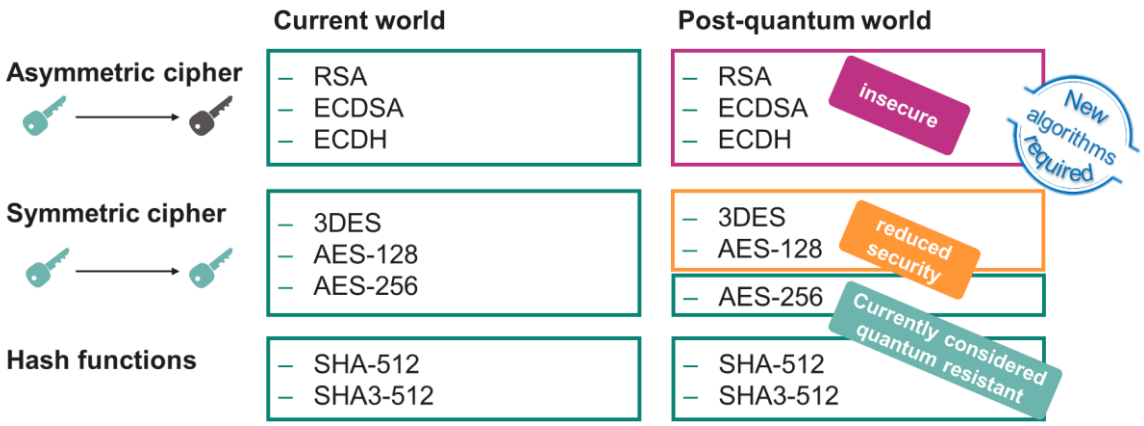
Example: AURIX™ TC4x cybersecurity cluster – designed for post-quantum algorithms and next generation security requirements

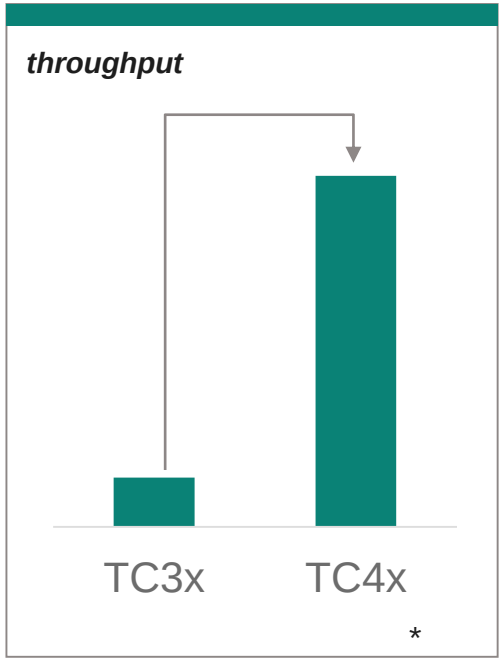
Traditional security methods are under attack …



- Connected cars are becoming more vulnerable
- Car computer and zone ECU designs require continuous update of security functions
- Quantum computing can be used to attack systems like RSA and ECC

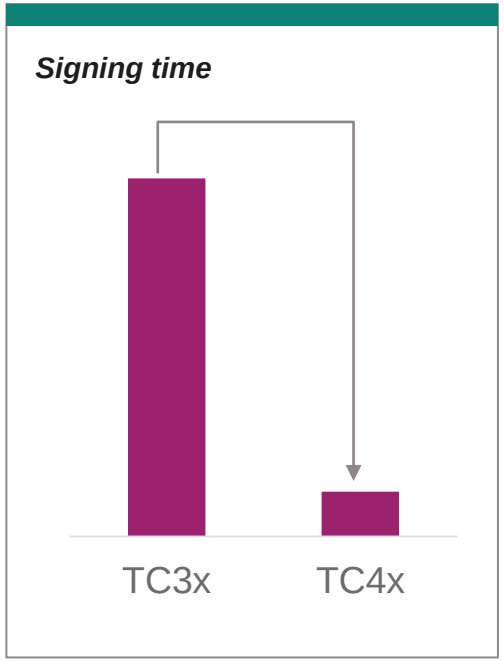
AURIX™ TC4x provides safety accelerator technology for latest security systems

Cipher-based Message Authent. Code (CMAC)



7x more throughput*

RSA 2048 on AURIX™ TC3x vs. PQC Dilithium 2 on TC4x



8x faster*

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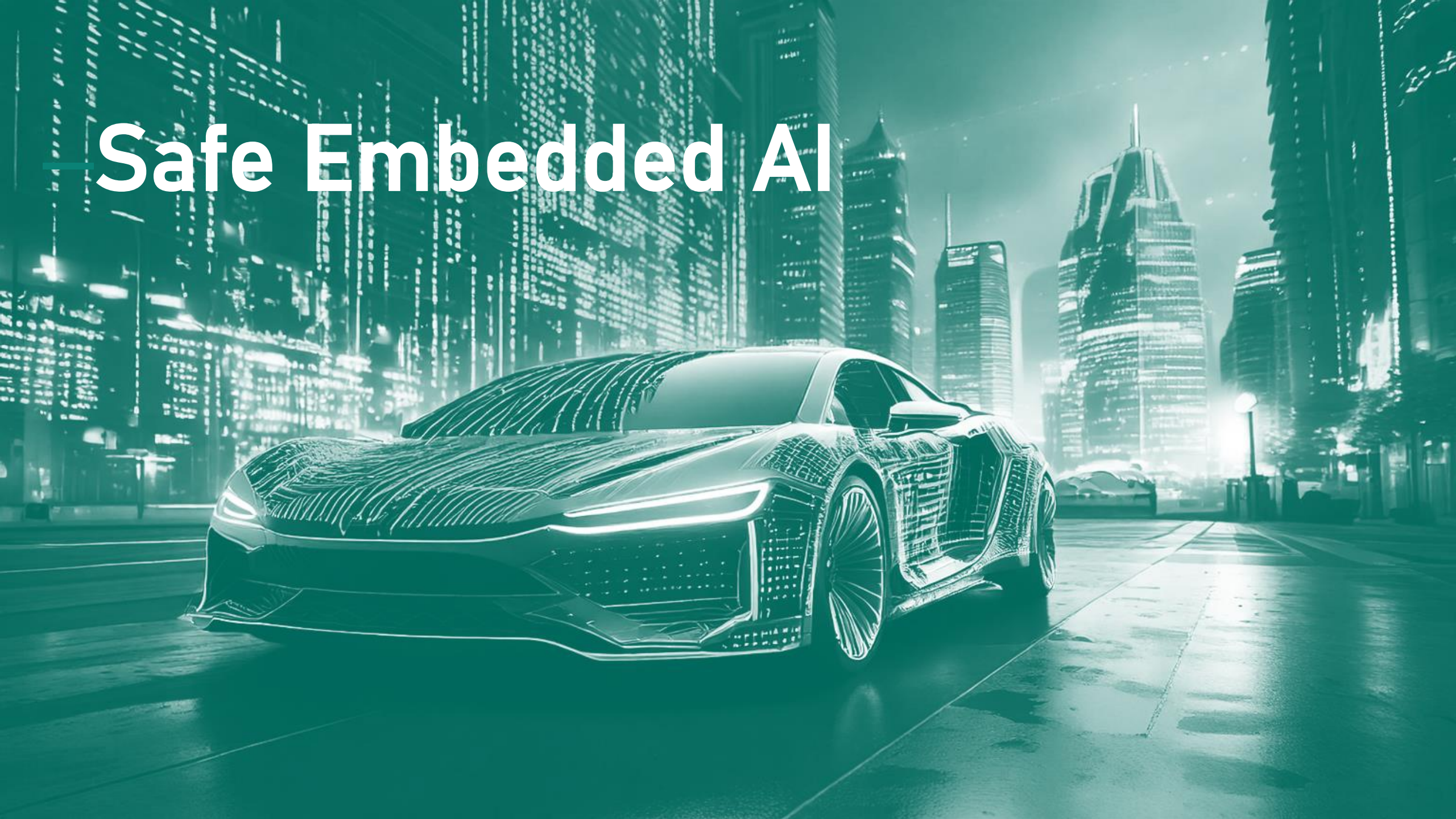
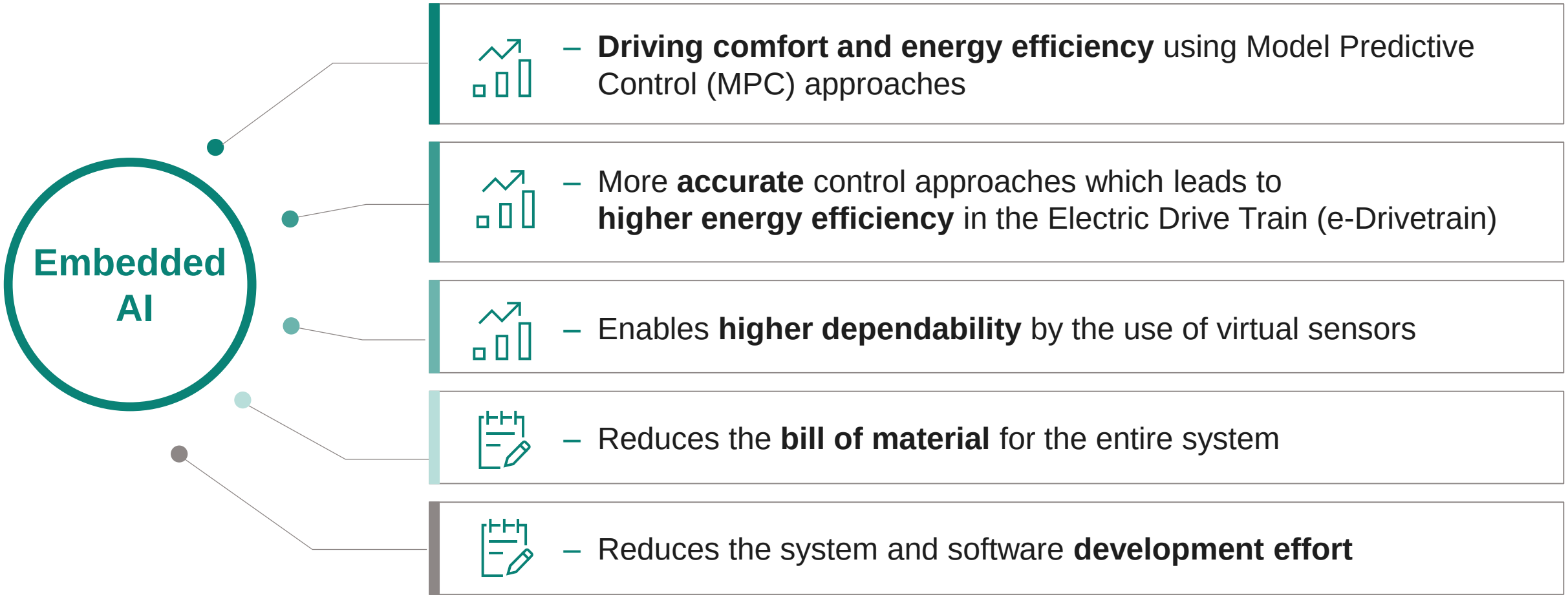
Safe Embedded AI



Embedded AI offers system-level benefits

Embedded AI enhances safety and real-time critical classical control and signal processing algorithms with data-driven Artificial Intelligence (AI) approaches



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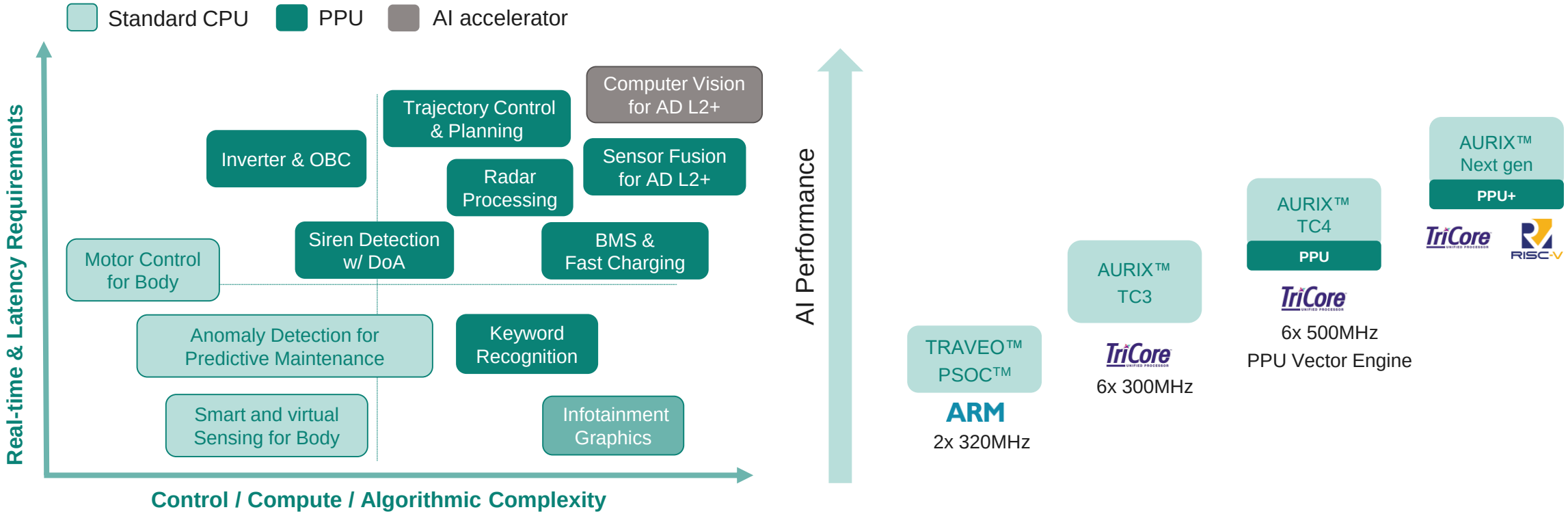
Embedded AI offers model predictive approaches

Model predictive approaches drive the Innovation for Autonomous Driving and Electric Vehicle



- Embedded AI enables **model predictive and model adaptive** approaches that can run on MCUs
- **Model predictive and adaptive** approaches are the **key technology** to increase energy efficiency, driving comfort and dependability for Autonomous Driving
- To solve the major challenges **driving distance and fast charging** for Electric Vehicle, **AI approaches** together with conventional models are the **game changer**

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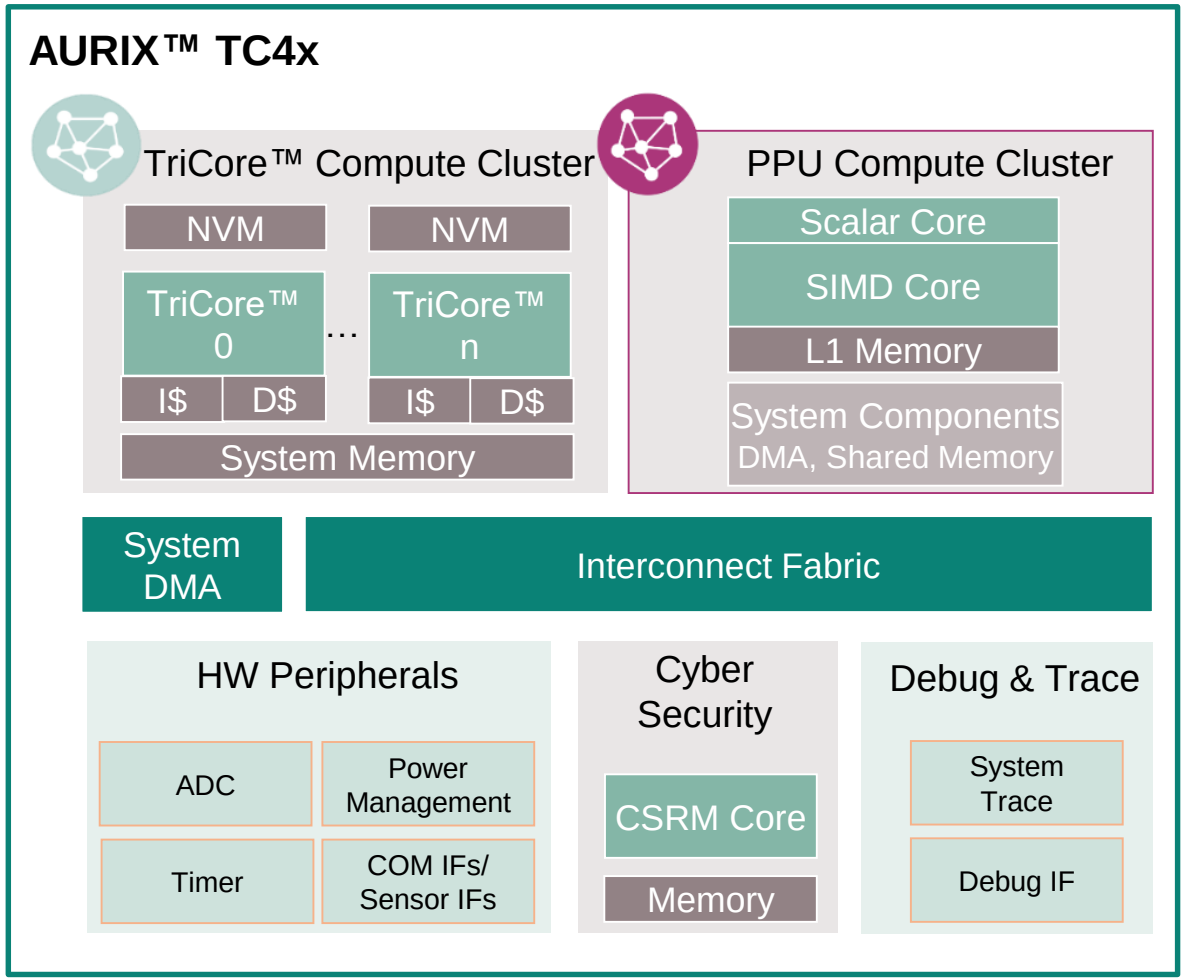
Example: New AURIX™ data processing architecture supports latest safe AI use cases with new accelerator technology



AURIX™ Safe Parallel Processing Unit

- SIMD vector DSP, speeding up computation compared to traditional CPUs
  - Matrix operation acceleration & Data processing
  - Neural network-based algorithms
  - High speed control implementations

AURIX™ SoC architecture

- Virtualization enables seamless functional integration
- PPU acts as a service provider, offloading TriCore™
- PPU is closely coupled to peripherals for low latency implementation

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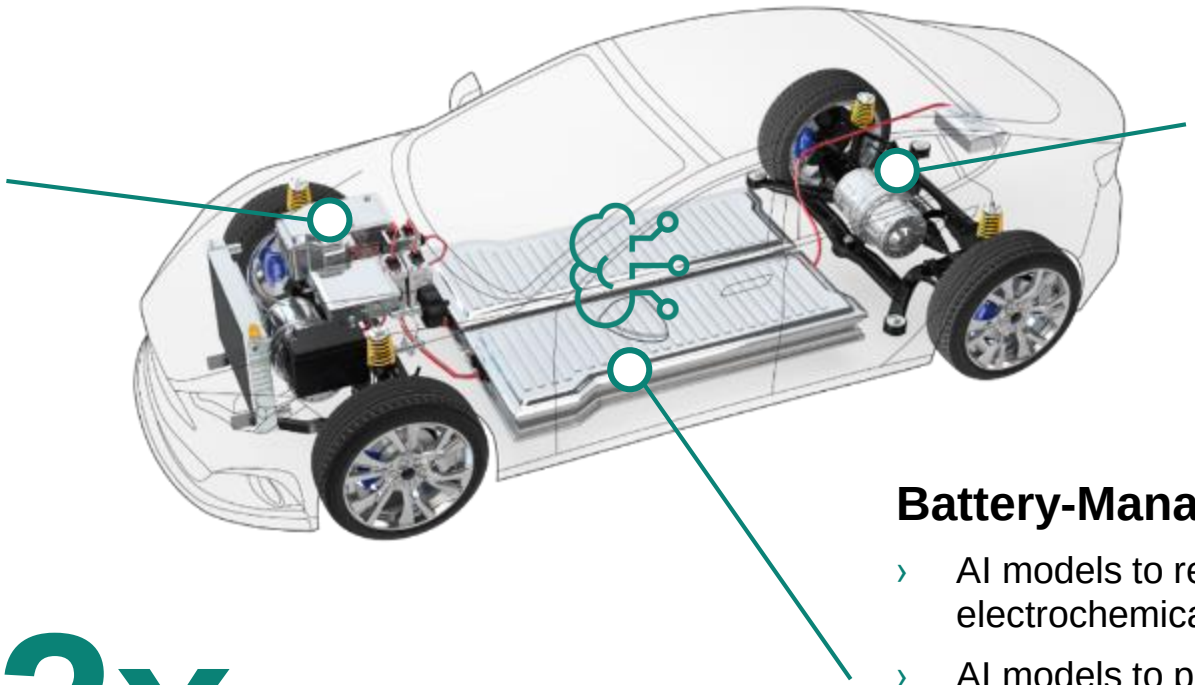
Embedded AI enables next generation electric drivetrain with significant efficiency gains in battery and power conversion

On-board Charger and DC-DC Converter

- Health Observing
- AI based load prediction
- AI based Model Adaptive Control (MAC)

clear cost-down path and further efficiency increase



HV Traction Inverter

- Motor Position Sensing
- Health Observing
- Temperature Estimation
- Model Predictive Control (MPC)

best-in-class system efficiency and cost-reduction

Battery-Management

- AI models to reparametrize electrochemical models during run-time
- AI models to predict battery status during fast charging

optimized charging, extended vehicle range and battery life

more than **12x**

TriCore™ performance, e.g. for AI-applications based on 256 bit PPU

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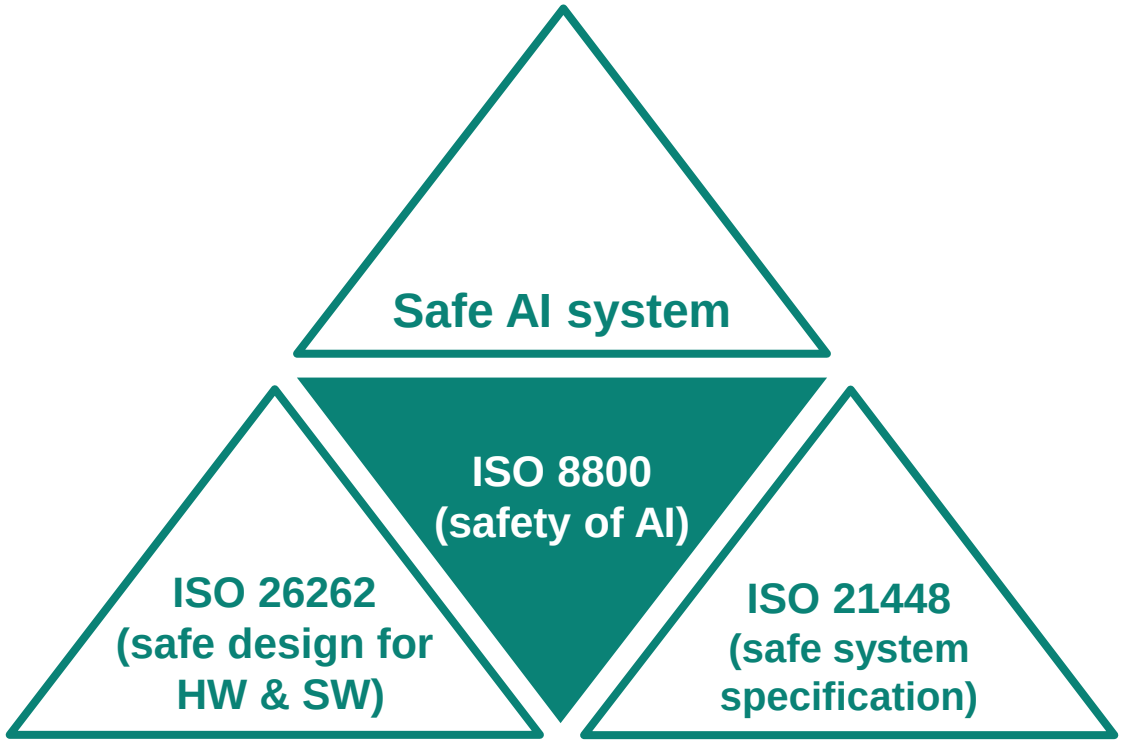
Functional safe AI systems require base standards
Industry-wide work groups established to define safety related AI system properties

1. Training data related to **Operational Design Domain** (ODD) are acquired
2. **AI model type** is selected and trained
3. AI models are **evaluated**, **verified** and **optimized** for the MCU
4. The validation of the AI model generalization is done by **integration** on the **application environment**



ISO 8800 (Safety of AI) in development to enable functional safe AI systems

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Key take-aways

– Modern microcontroller architectures are key for delivering the cost and performance promise of the Software Defined Vehicle (SDV)

– Open-source technologies enter the automotive domain – industry leaders joined forces to move RISC-V forward

– Post-quantum security solutions are a key area of innovation in the automotive domain

- Safe AI technologies build the basis for more power-efficient systems, lower BoM cost and improved dependability

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