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# The 4SDV Concept

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# MOVING BEYOND THE HYPE

## Reality counts more than vision

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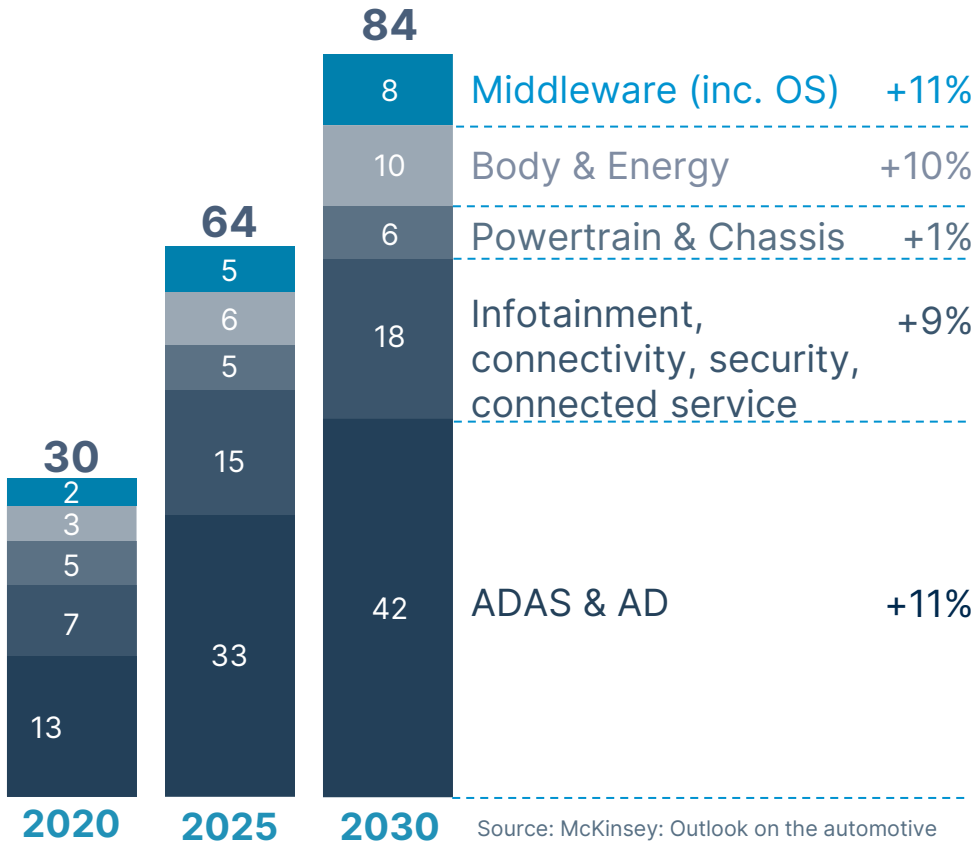
EV/Sales Development
(since Jan 2021):

| Average | L3M | L6M | L1Y |
|---|---|---|---|
| ADAS & Sensors[1] | 4.8x | 5.4x | 9.7x |
| Automotive Software[2] | 3.5x | 3.4x | 3.8x |
| Diversified Auto Tech[3] | 0.9x | 0.9x | 0.9x |
| Industrial Software[4] | 9.8x | 9.4x | 9.3x |

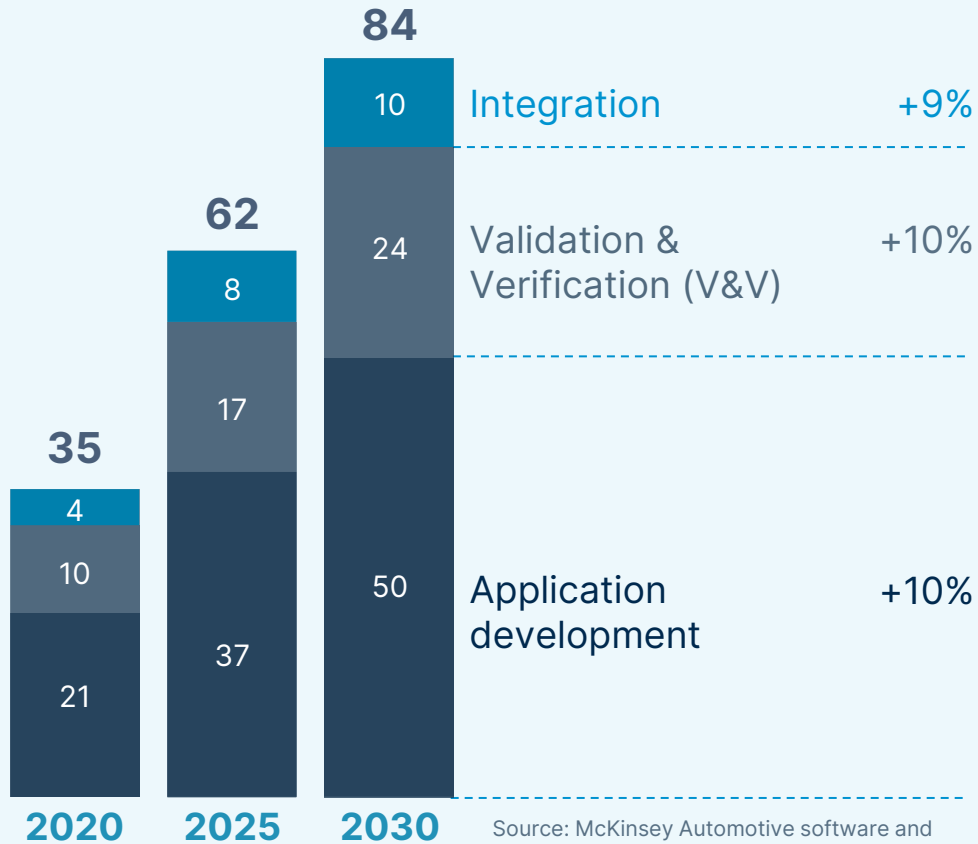

Provided by Goldman Sachs Source: Bloomberg, Capital IQ, IBES as of 15-Aug-2023

# Increasing Focus On Software

- E/E design shift towards more centralized architectures
- Software defined vehicles: most complex software products
- Requiring an orchestration layer, enabling safety and security




Source: McKinsey: Outlook on the automotive software and electronics market through 2030; published 2023; in bn €

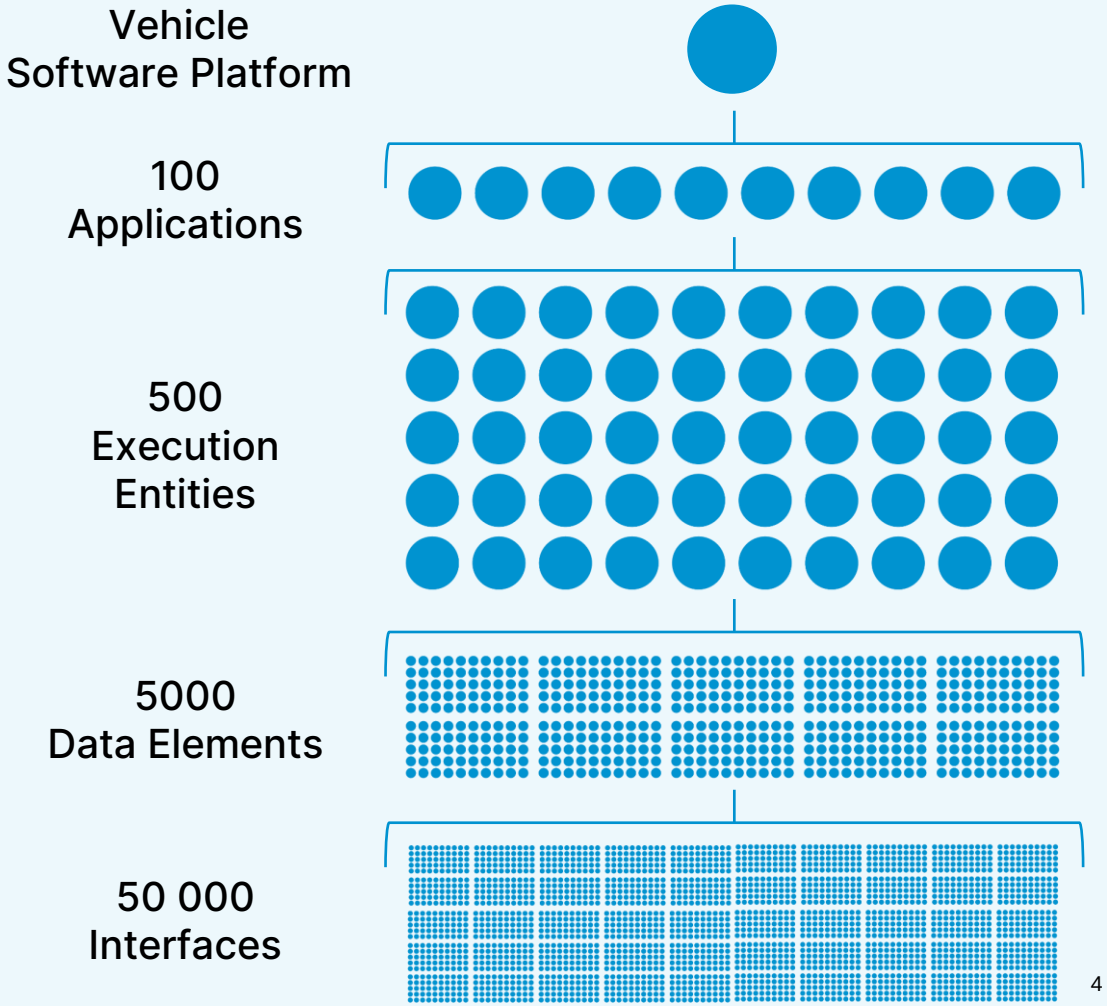



Source: McKinsey Automotive software and electronics 2030; published 2017; in bn €

# Market Development

(World Economic Forum, BCG analysis):


## The Vehicle Software Platform in numbers for an ADAS L2 Domain Control Unit.



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# Automotive stack overview

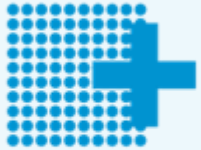
## Middleware layer is managing complexity

- Toolchain
- Applications
- Domain Functions
- Middleware
- Basic Software
- OS/Hypervisor
- Hardware

# Industry challenge

## Complexity & Safety

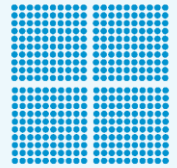
**SYSTEM CONSTRAINTS**



100+
TIME, LATENCY, PRESEDENTS CONSTRAINTS ETC.

**SOFTWARE DEMANDS**

100
APPLICATIONS



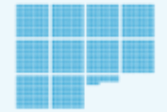
400
TASKS

**COMPUTATION UNIT RESOURCES**

46
CPU CORES

6
HARDWARE ACCELERATORS

2
TSN SWITCHES



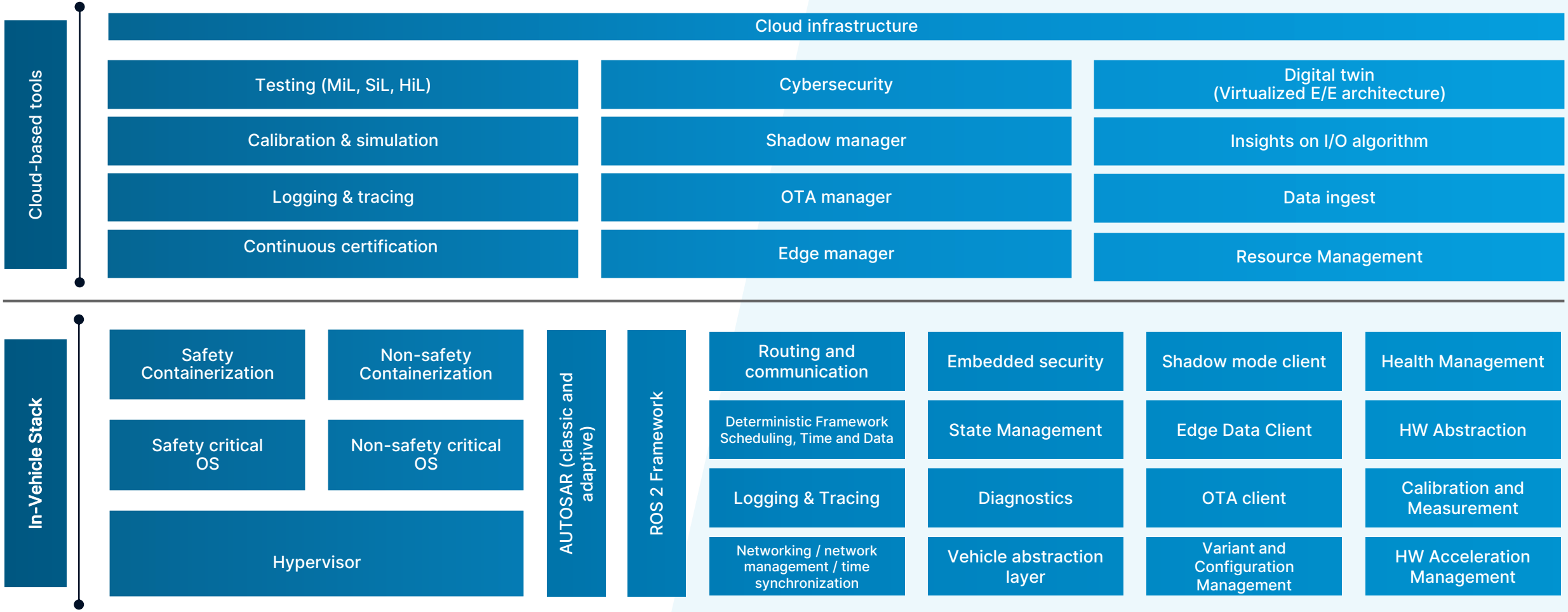
1024
VIRTUAL LINKS

**SOLUTION SPACE**

- $10^{5000}$ without any constraints
- $10^{500}$ messages and tasks must not overlap
- $10^{80}$ atoms in the universe
- $10^{5}$ valid configurations with all constraints

The challenge is to efficiently search an enormous solution space to find valid configurations.

# Landscape of in-vehicle & cloud-based software stack



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# From
## Software Defined Vehicle (SDV)

"The gradual transformation of automobiles from highly electromechanical terminals to intelligent, expandable mobile electronic terminals that can be continuously upgraded."
Deloitte, 2021

- Over-the-air updates
- Connected vehicle features
- Customization

# To
## 4S Defined Vehicle (4SDV)

Software alone is not enough. It takes a combination of:

- **S**ystems
- **S**afety
- **S**ecurity
- **S**oftware

To accommodate the transition to:

- Centralized E/E architecture
- Complex ADAS and AD systems

# 4SDV for modern E/E Architectures

## System

- System engineering approach that considers safety, security, availability, ease of integration and updatability right from the start
- Signal to Service w/ End-to-End time boundary
- Ensure deterministic behavior across SoCs and DCUs

## Safety

- Architecture that addresses functional goals and safety
- Safe real-time execution of software components (SWCs)
- Safe and secure communication of SWCs

## Security

- Secure Boot
- Secure Over-The-Air-Updates
- Secured Edge to Cloud communication

## Software

- Software integration process, fully automated via tooling
- Serviced Oriented Architecture (SOA)
- Automatic software unit certification

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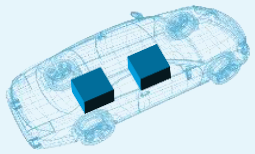
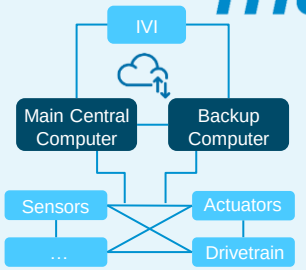
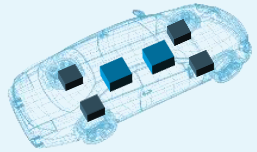
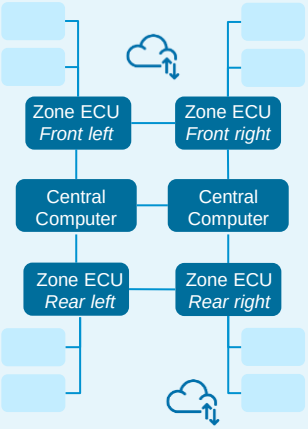


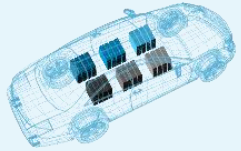
**Centralized E/E architecture**
(2 ECUs : n functions)



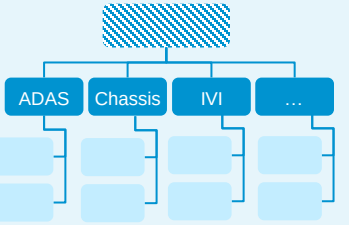



**Zone-based E/E architecture**
(6 ECUs : n functions)

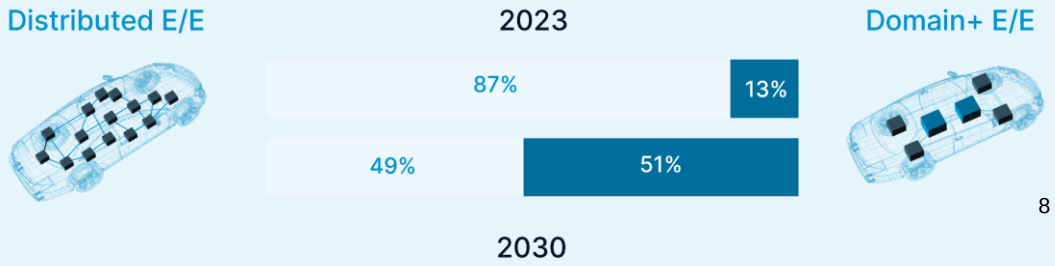


**Domain E/E architecture**
(5-7 ECUs : n functions)




Split in % of Vehicles



# 4SDV for ADAS/AD

## System
- Time and Data Determinism
- Computation Chains
- Fail Operational Architecture

## Safety
- Mixed-Criticality
- Safety-by-design
- ISO26262 up to ASIL-D
- Fail Operational

## Security
- ISO 21434
- Security-by-design, state-of-the-art cybersecurity process
- Proactive defense (e.g Intrusion Detection System)

## Software
- Fast Validation & Verification
- Deterministic Re-simulation
- Cloud to edge parity

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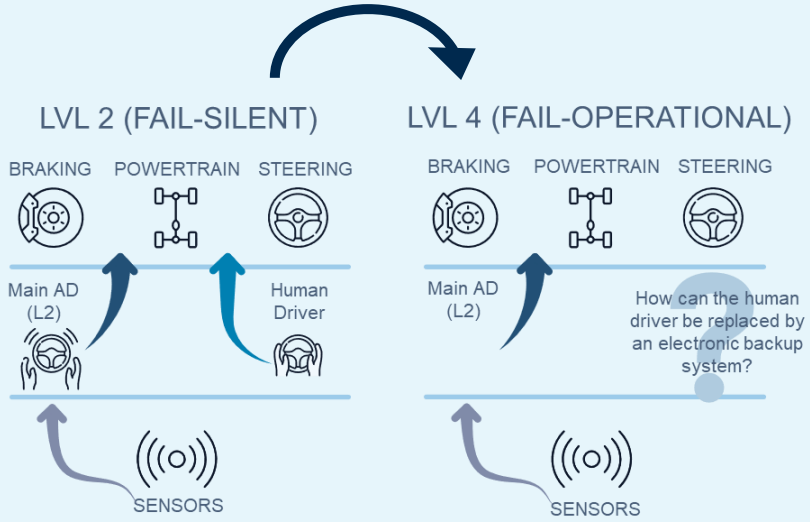
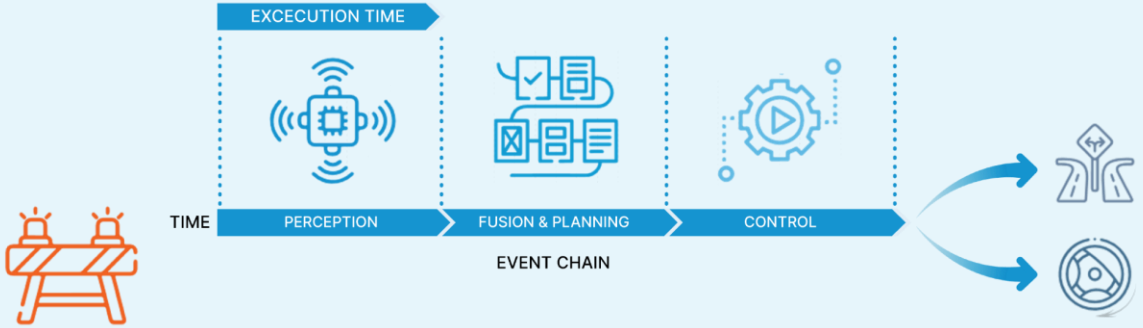
# Architectural View




# Software View

Sense – Think - Act



# Systematic partitioning into independent Fault Containment Units, to address the „impossibilities“

It is **impossible** to avoid **single event upsets** (e.g., bit flip) in non-redundant hardware during the life-time of an ultra dependable system

It is **impossible** to establish the ultra-high dependability of a large monolithic system by **testing and simulation**

It is **impossible** to find **all design faults** in a large and complex monolithic software system

It is **impossible** to precisely specify **all edge cases** that can be encountered in driving situations

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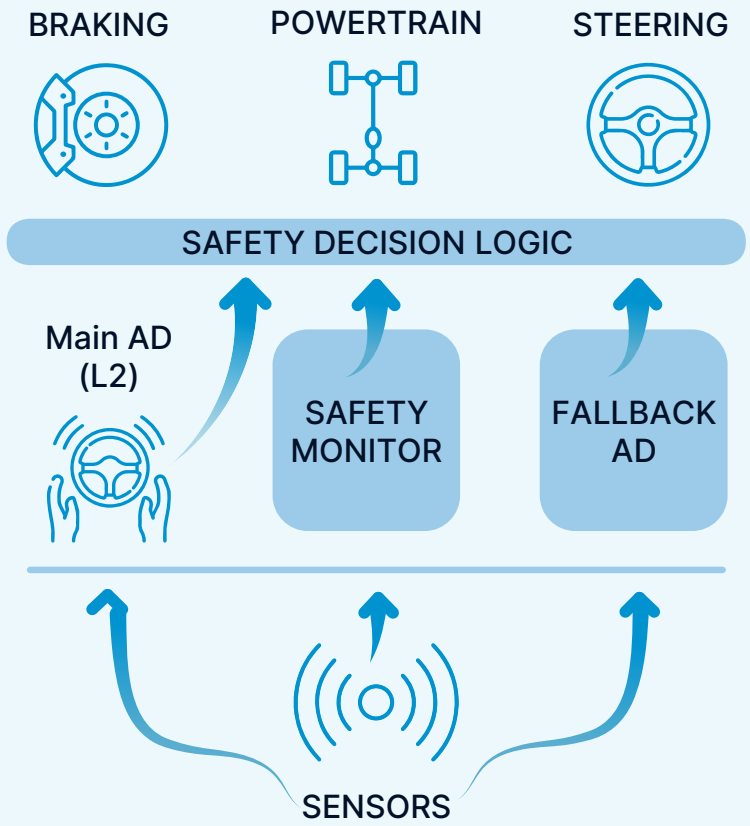
# Resilient Safe Architecture (RSA)

## TTTech Auto Reference Architecture for Fail-Operational Systems



# Fast Loop Development

From design to deployment as fast as possible prevailing system integrity

App development based on standardized frameworks: AUTOSAR, ROS2

Assisted learning : Timing, Execution, E2E properties

Simulation supported by cloud to edge parity virtualization.

Consistent re-simulation, speeding-up verification

Embedded / edge software integration with E2E properties behavior

Automatic software certification

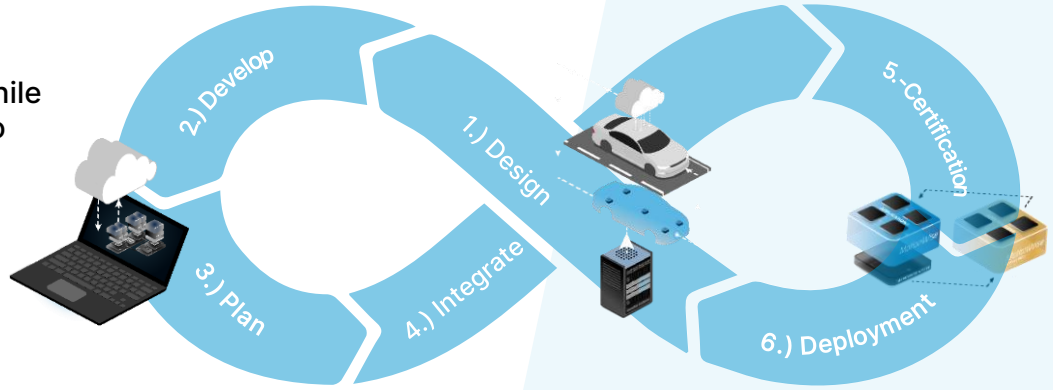
**System Verifier (Phase 1)**
- Enables early system definition flaws identification

**Learn & Freeze (Phases 1-2)**
- Enables distributed app development while providing relevant system information to integrators

**Middleware Creation (Phase 1, 3, 4)**
- Creation of full middleware: SoC, OS, AUTOSAR, Topology selection and configuration according application specification

**Scheduling Suite (Phase 3)**
- Automatic app and communication scheduling, enabling end-to-end behaviors

**SW Factory (Phase 6)**
- Continuous deployment, validation & verification. Integration with OEM pipeline




MotionWise Creator

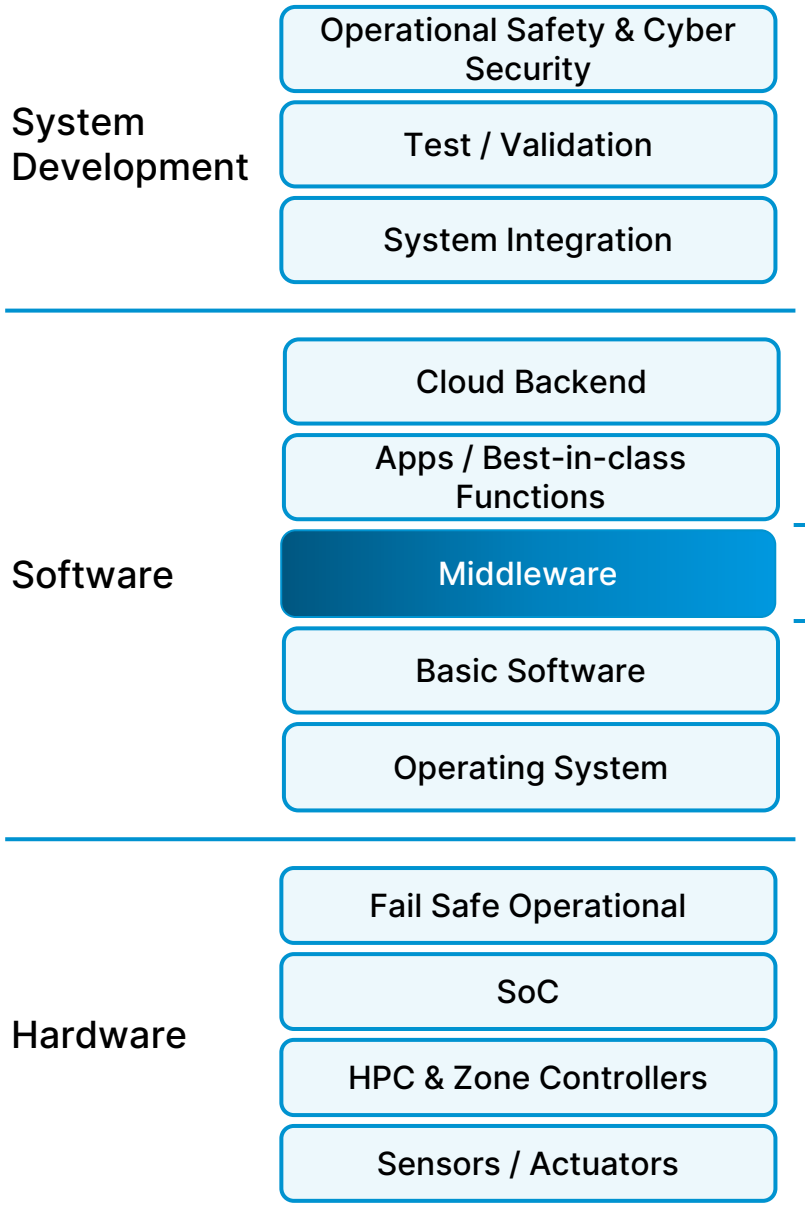
MotionWise SDK

**Virtual ECU (Phase 2-4)**
- Cloud-edge parity
- Virtual environment for SoC, and multi-ECU

**Software In the Loop Environment (Phase 2-4)**
- API abstraction for early development in simulated environments

**Deterministic Re-simulation (Phase 4-5)**
- Enable deterministic re-simulation

# Automotive Stack




MotionWise

TTTech Auto portfolio provides all the components to create the middleware for safety critical application

| Description | Competitive Advantage |
|---|---|
| Workload Planning & Orchestration | • Safe-by-design (ASIL-D) application execution<br>• Time and Data-flow deterministic application execution<br>• Right-by-design scheduling (app + network) |
| Communication | • Safe (ASIL-D) Deterministic SoC to SoC communication<br>• Standardized API<br>• Time Sensitive Networking (TSN) and PCIe communication |
| Time Synchronization | • Safe (ASIL-D) time synchronization enabling time determinism |
| Health Management | • Global error management system<br>• Supervision |
| Virtualization & Simulation | • Cloud to edge parity virtualization<br>• Deterministic re-simulation for app development and debugging acceleration |
| Standard friendly | • Integration with classic & adaptive AUTOSAR<br>• ROS2 support for quick prototyping |

# Business Impact & Economical Benefits

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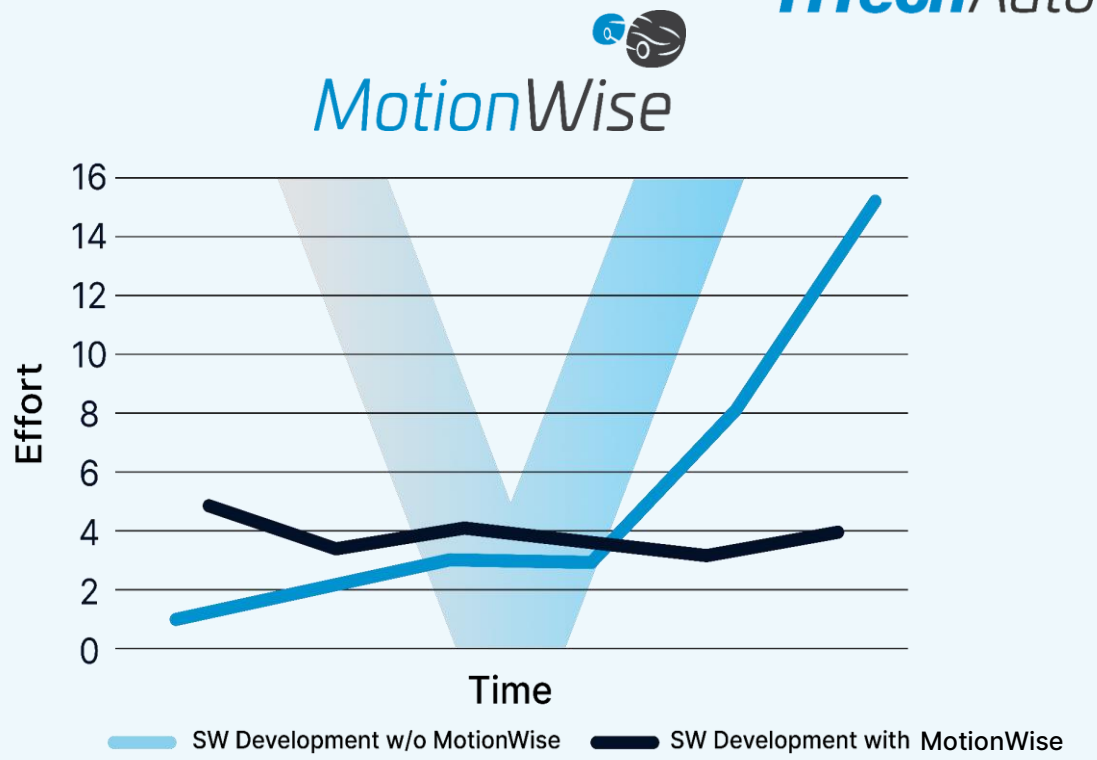
## Challenges faced by OEMS during complex E/E or ADAS/AD programs:

- Unpredictable efforts on software integration
- Unpredictable efforts on V&V
- Higher efforts on testing
- Higher efforts on debugging

- Start of production (SOP) shifts
- Reduced functionality at SOP



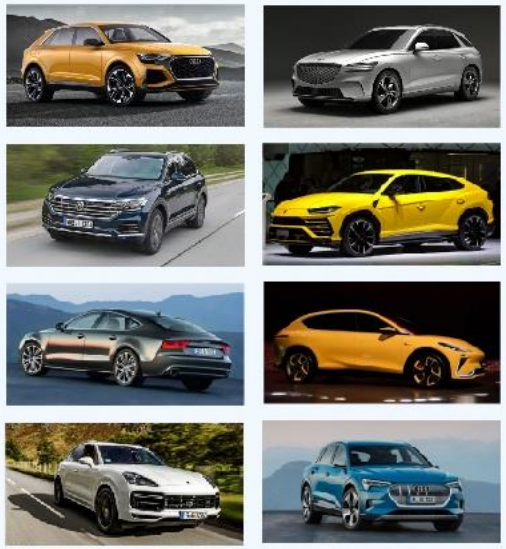

Better utilization of hardware resources

Faster functional integration

Less effort for validation & verification

# MotionWise, the 1st series proven safe vehicle software platform for DCUs deployed already on more than 2.000.000 cars.

## 9.500.000 cars in the pipeline



2018 - 2023 | 2024/5 | 2026/7 | 2028

# Summary: Benefits of 4SDV

## Thinking in Systems

Together with Safety, Security and Software, thinking in systems is key to enable ADAS/AD functionality and modern E/E architectures

## Development Acceleration

Enabling fast development while keeping the system integrable

## Industrializing Software

Software integration process, fully assisted via tool process, covering the different stacks in the Vehicle Software Platform (OS, BSW, Middleware)