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22-23 SEPTEMBER 2020

Gregor Sievers, Ph.D.
dSPACE GmbH

How MIPI® Interfaces Solve Challenges in ADAS/AD Sensor Validation

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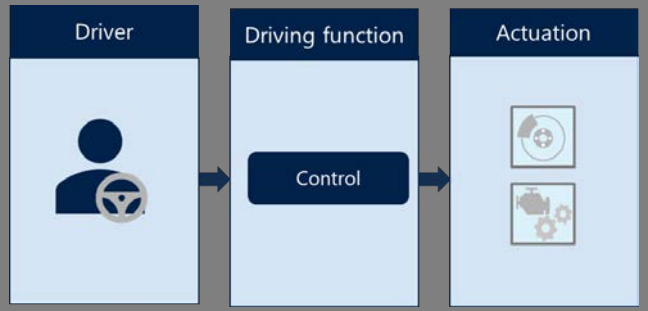
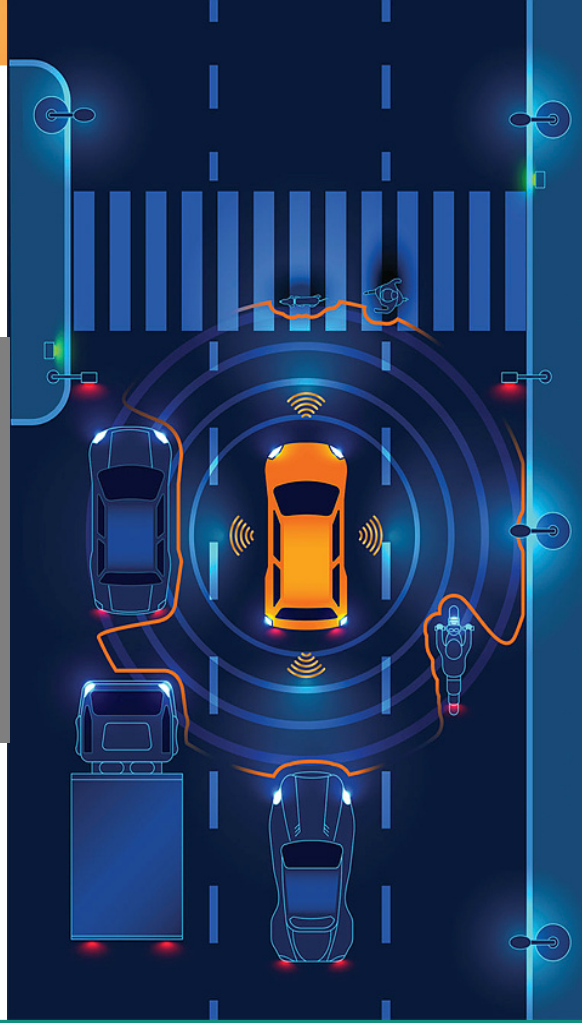
Vision „Autonomy“

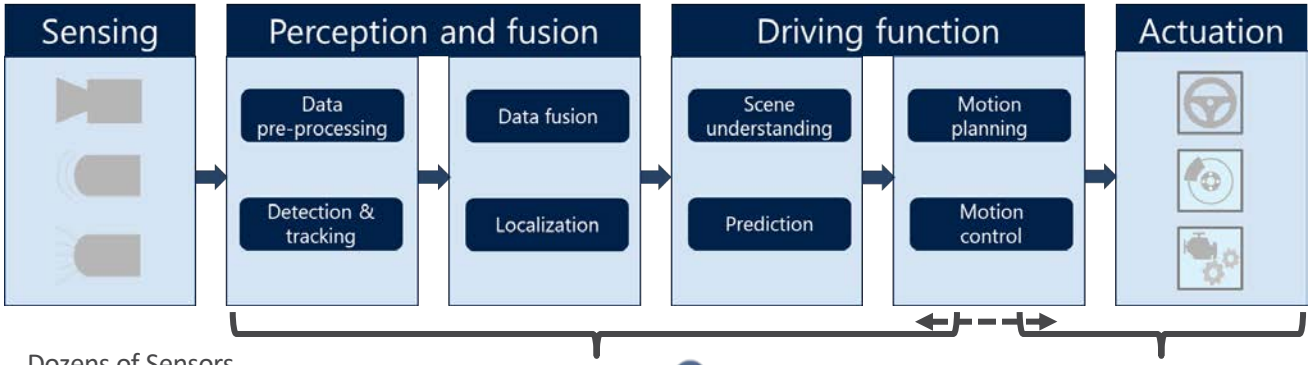
From simplicity





Vision „Autonomy“

Towards complexity

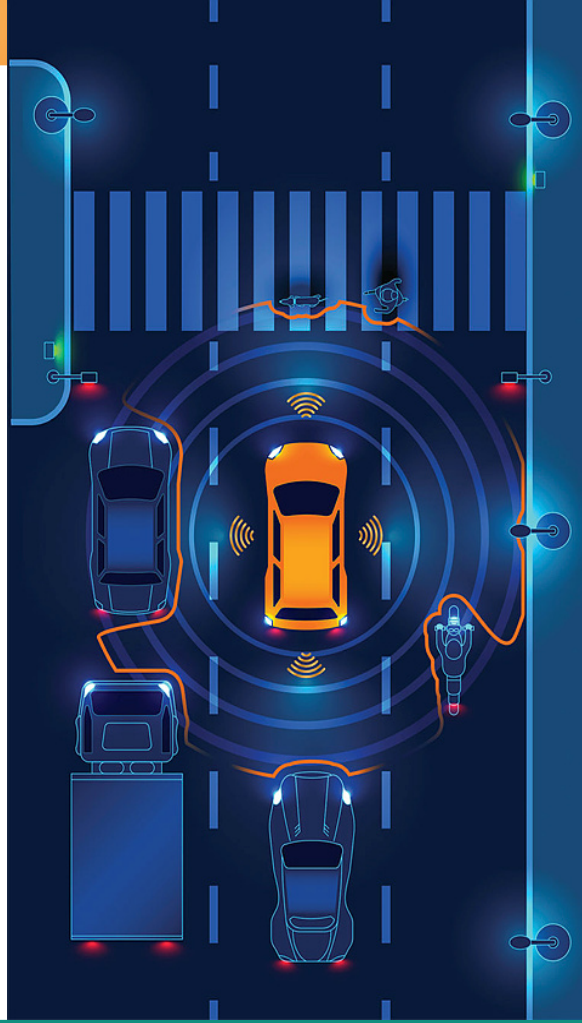


Dozens of Sensors
- Camera
- Radar
- Lidar

High Data Rates
- Dozens of Gbit/s

Artificial intelligence

Hard real-time processing
- Functional safety
- …

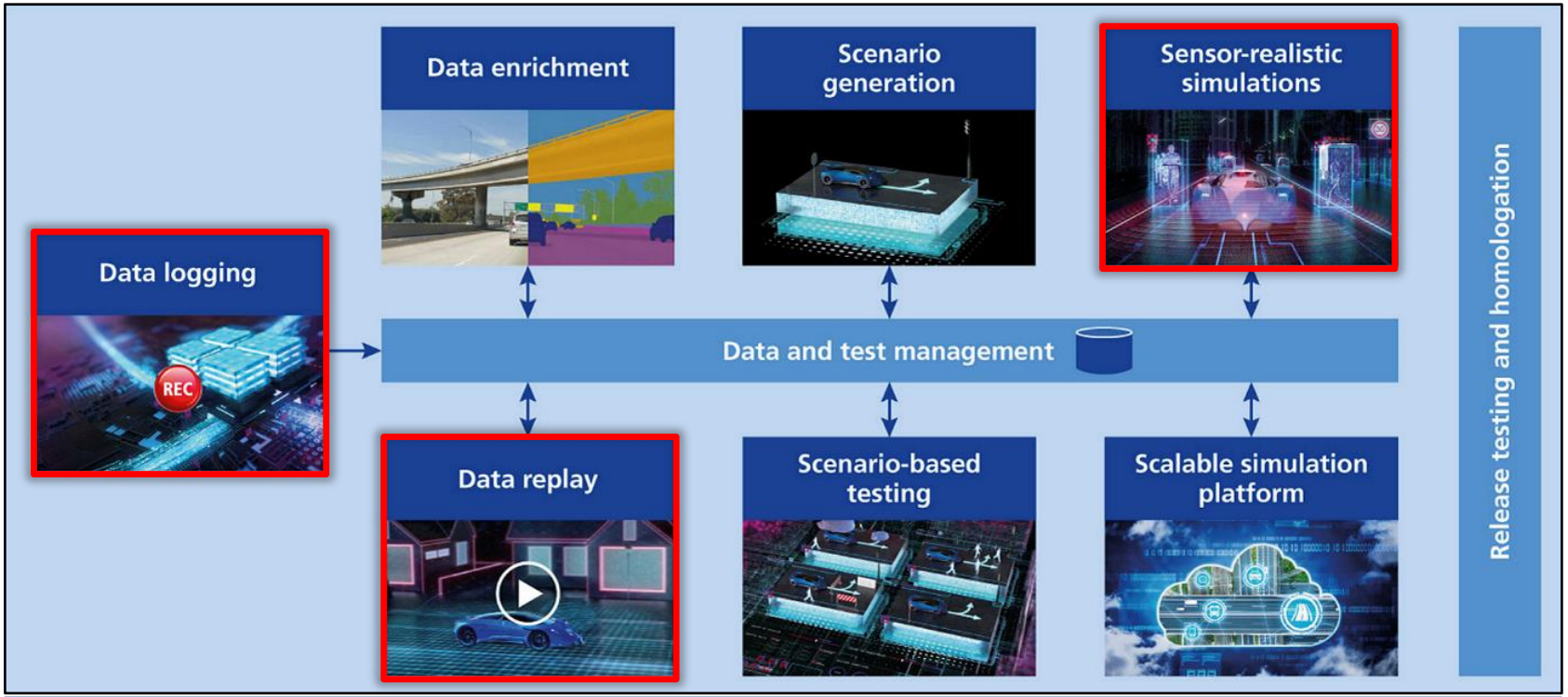


Vision „Autonomy“

Validation of sensors today

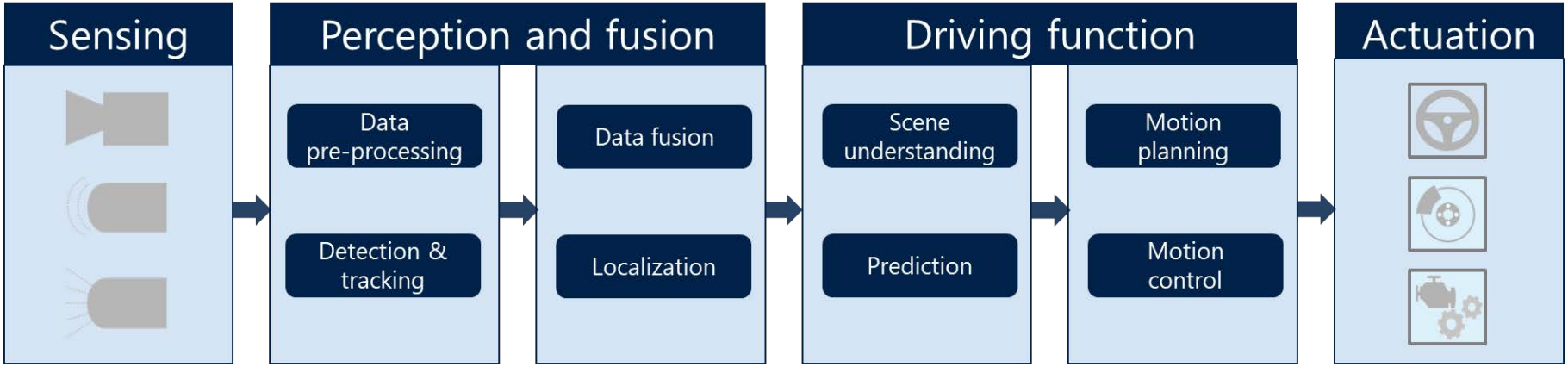
- Real test drives
  - Expensive
  - Lot of data
  - Critical situations
  - Sensor hardware upgrade

Data-driven development and validation



dSPACE AD validation solution

AD software stack – Validation and release testing



Sensor front end tests

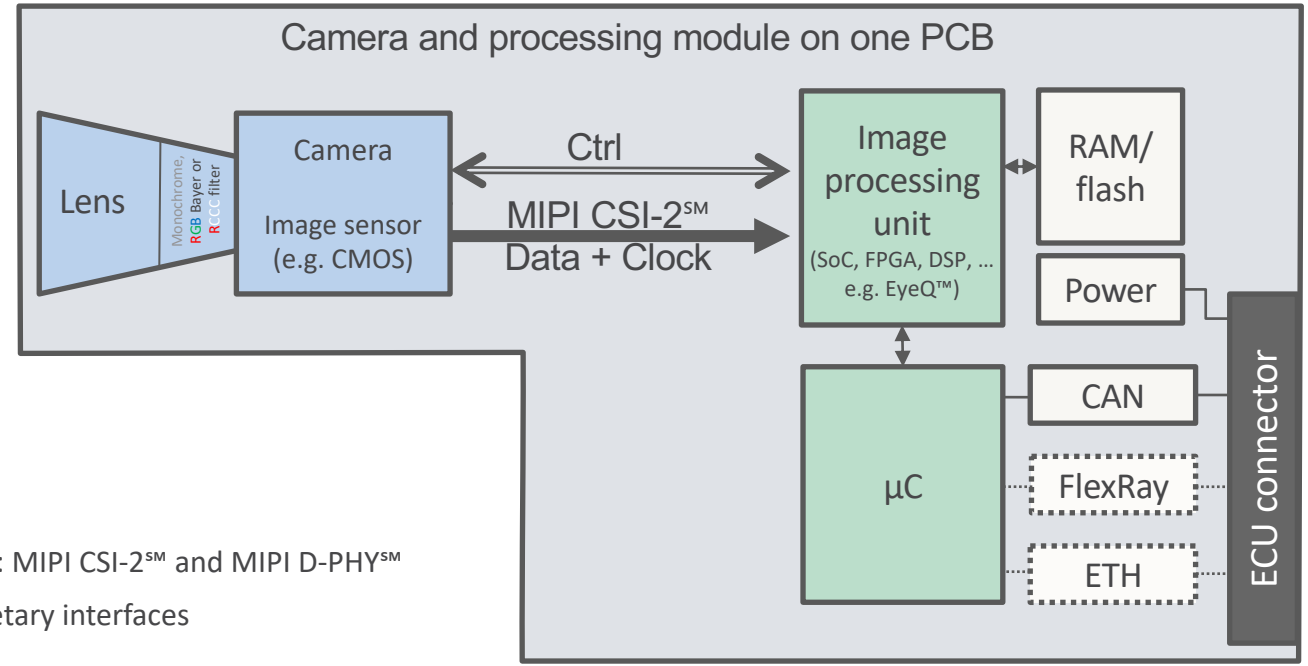
Data replay tests

Closed-loop SIL and HIL simulation

Real test drives

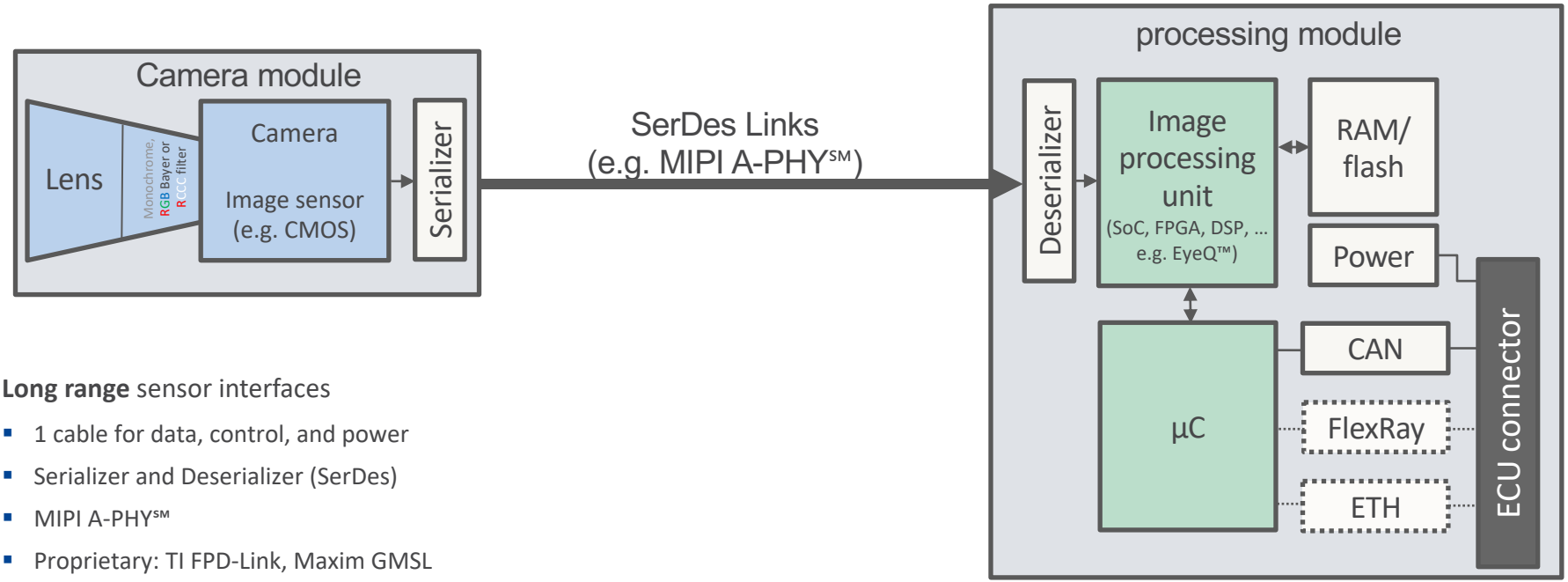
SIL: Software in the Loop
HIL: Hardware in the Loop

Automotive Front Camera Architecture



- **Short range** sensor interface: MIPI CSI-2℠ and MIPI D-PHY℠
- MIPI CSI-2℠ replaced proprietary interfaces
  - Parallel
  - LVDS
- Also used for Radar and Lidar applications

Automotive Surround View Camera Architecture



- **Long range** sensor interfaces
  - 1 cable for data, control, and power
  - Serializer and Deserializer (SerDes)
  - MIPI A-PHY℠
  - Proprietary: TI FPD-Link, Maxim GMSL

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Data Logging of ADAS/AD Sensors

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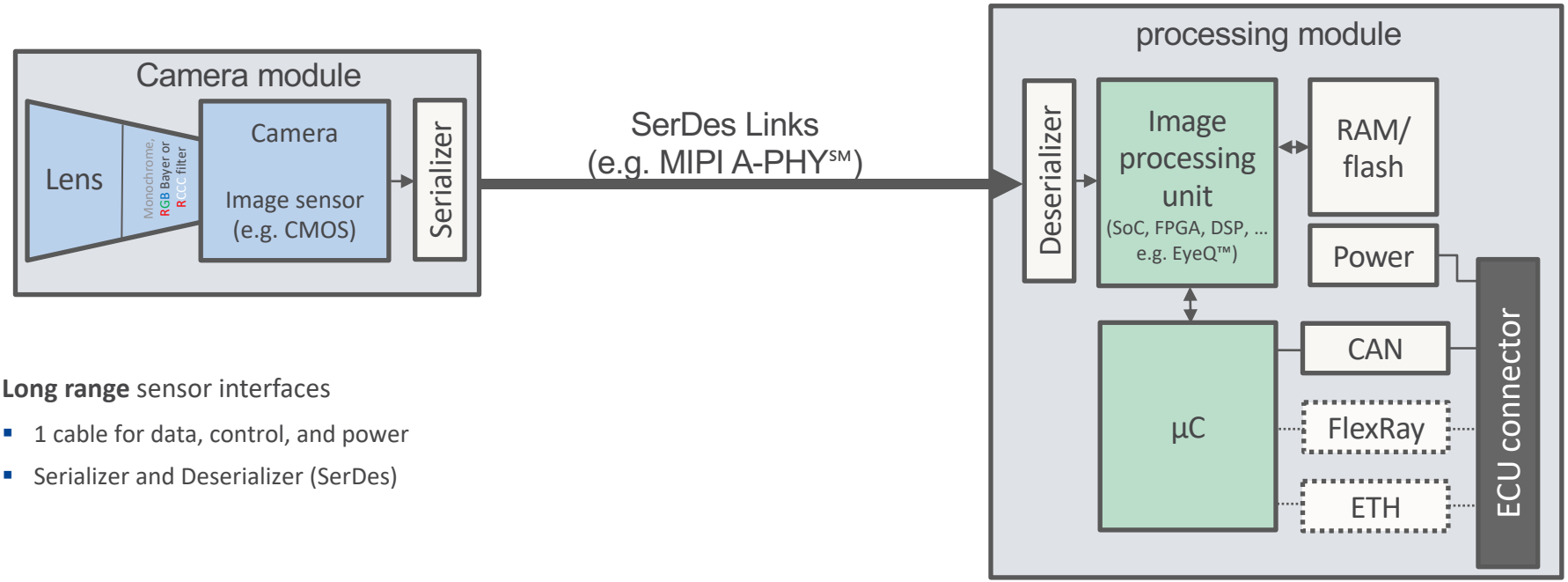
Automotive Surround View Camera Architecture



- **Long range** sensor interfaces
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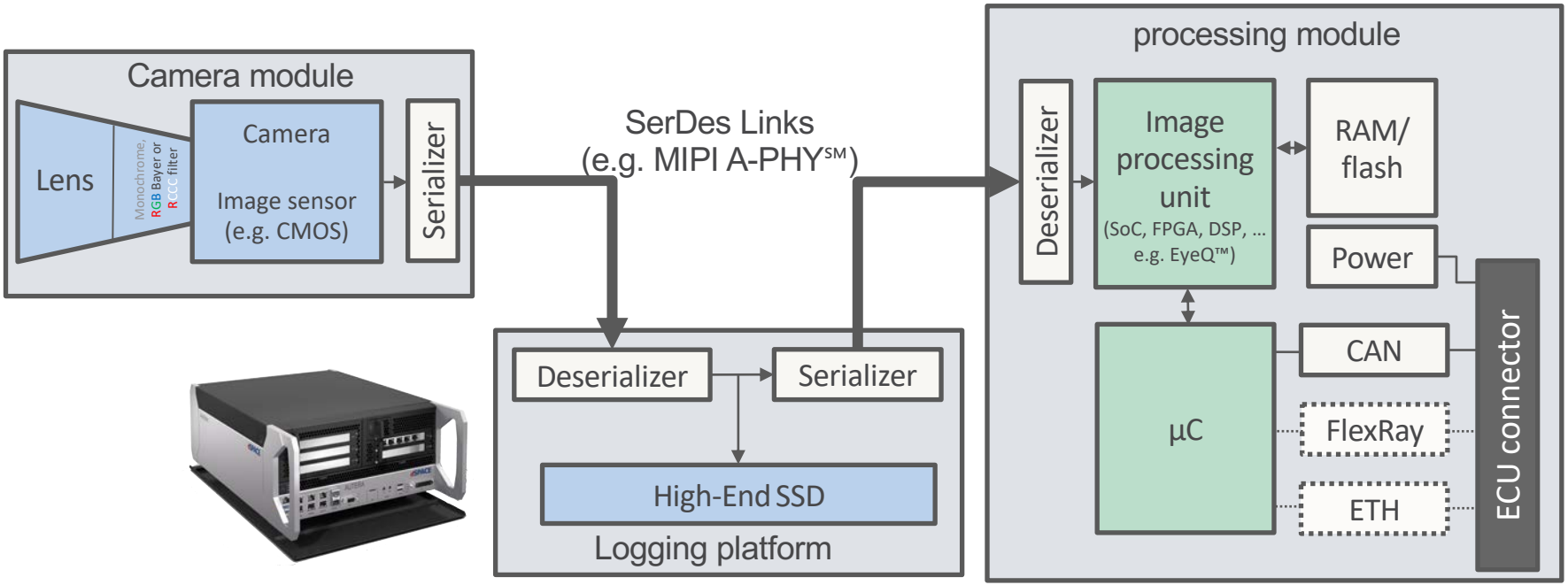
Surround View Camera: Data Logging with ECU



Data Logging and Prototyping for ADAS/AD

dSPACE AUTERA - The power of a Server – in the vehicle!

- Intel Xeon CPU with 12 Cores (@2GHz)
- Support for CAN, Automotive Ethernet, etc.
- Up to 6x PCIe slots for extensions

- High End Data Logging Capability
  - Up to **64 TB** Storage
  - Up to **50 Gbit/s** logging bandwidth

- PCIe Grabber Card for Sensor Interfaces
  - **Maxim GMSL** and **TI FPD-Link**
    - Up to 6 Gbit/s per sensor
  - Additional Interfaces under development
    - MIPI A-PHY℠ once available

Mainboard I/O-Rack
10GbE, USB 3.0, and 1GbE

General Purpose I/O, USB 3.0, SIM-Slot and User-LEDs
For additional sensor connections,
Wireless Connectivity,
Status-Info

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Virtual test drives

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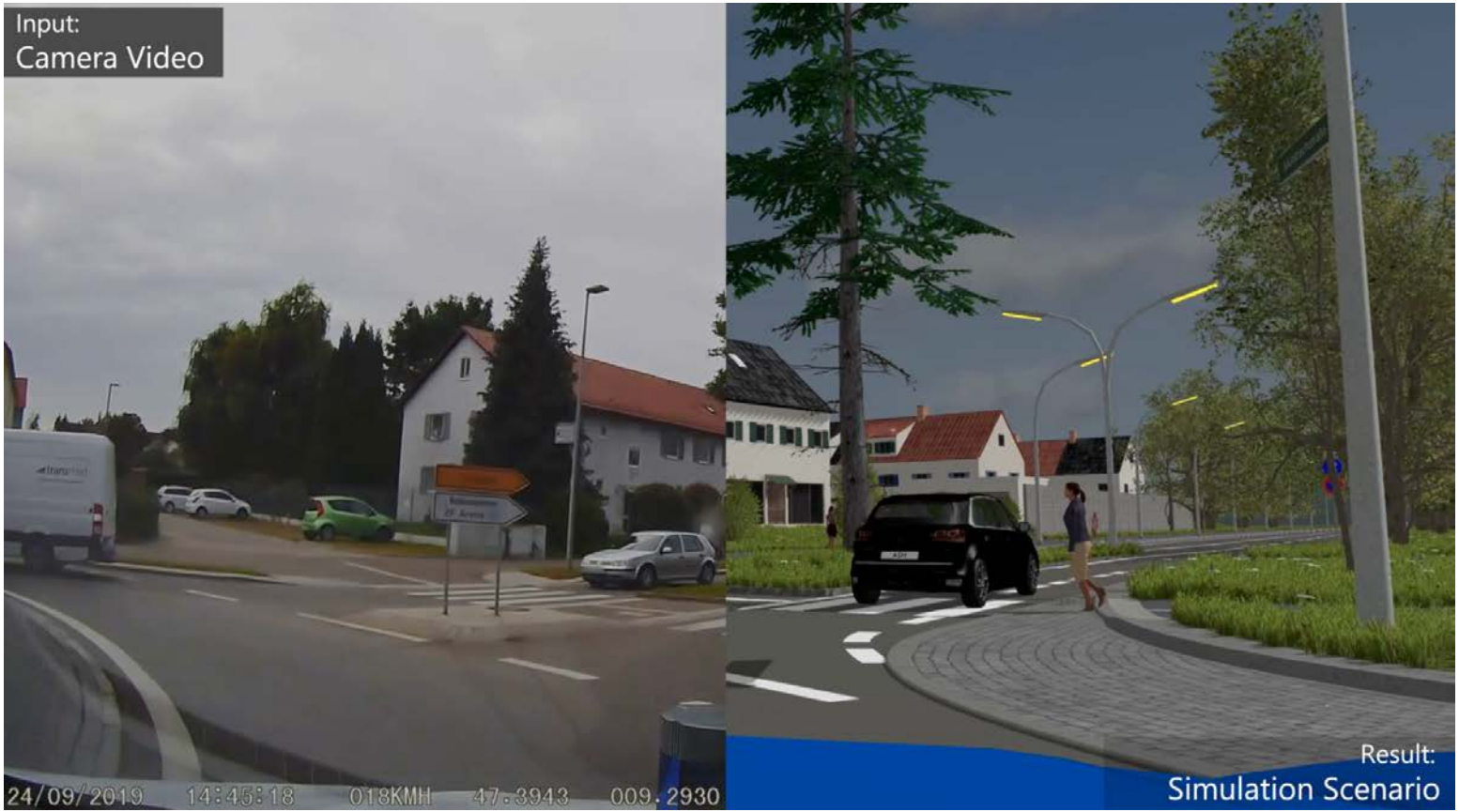
Video: Recorded and Simulated Test Data



AD software stack – Validation and release testing

Virtual test drives – SIL simulation

Virtual test drives – HIL simulation

Real test drives

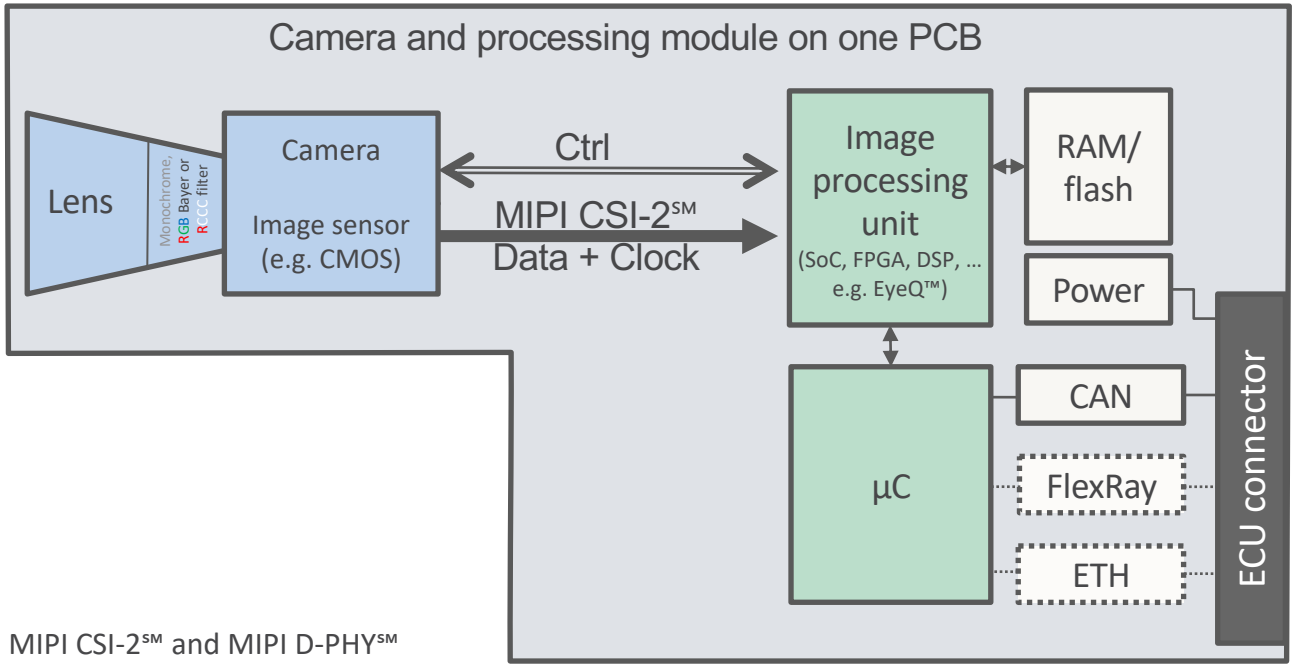
Virtual ECUs

PC cluster

Real ECUs

SIL: Software in the Loop
HIL: Hardware in the Loop
ECU: Electronic Control Unit

Front Camera: Hardware in the Loop testing



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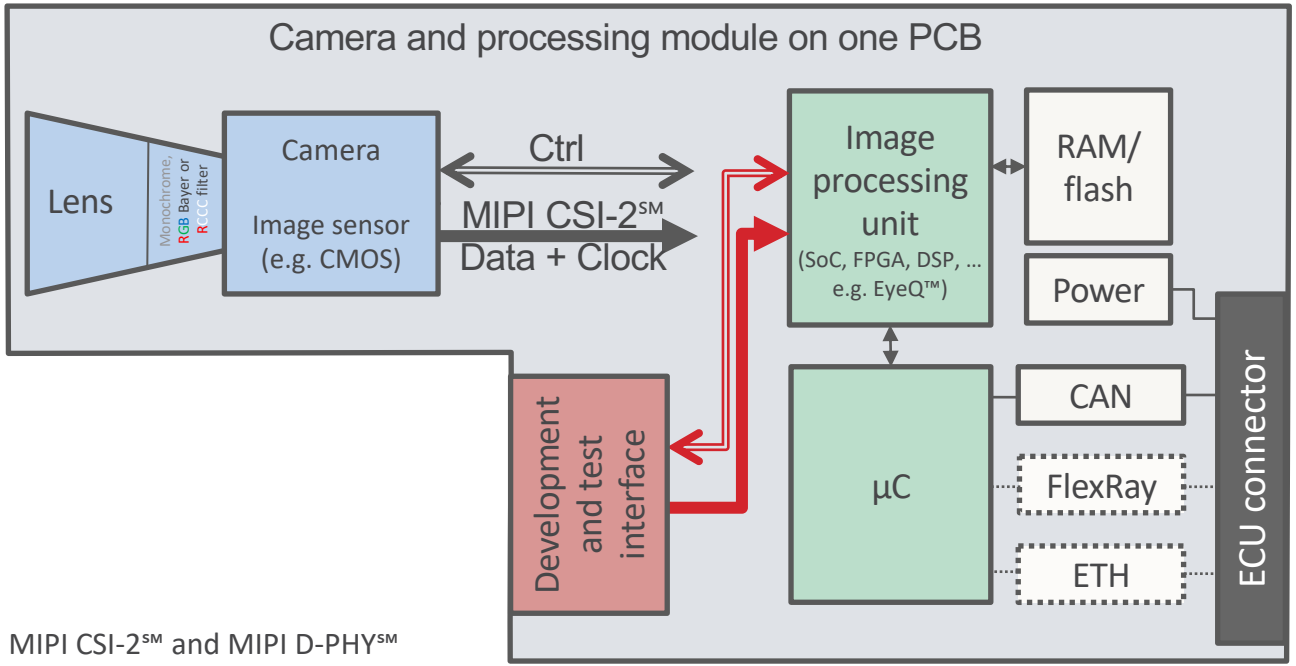
Front Camera: Hardware in the Loop testing



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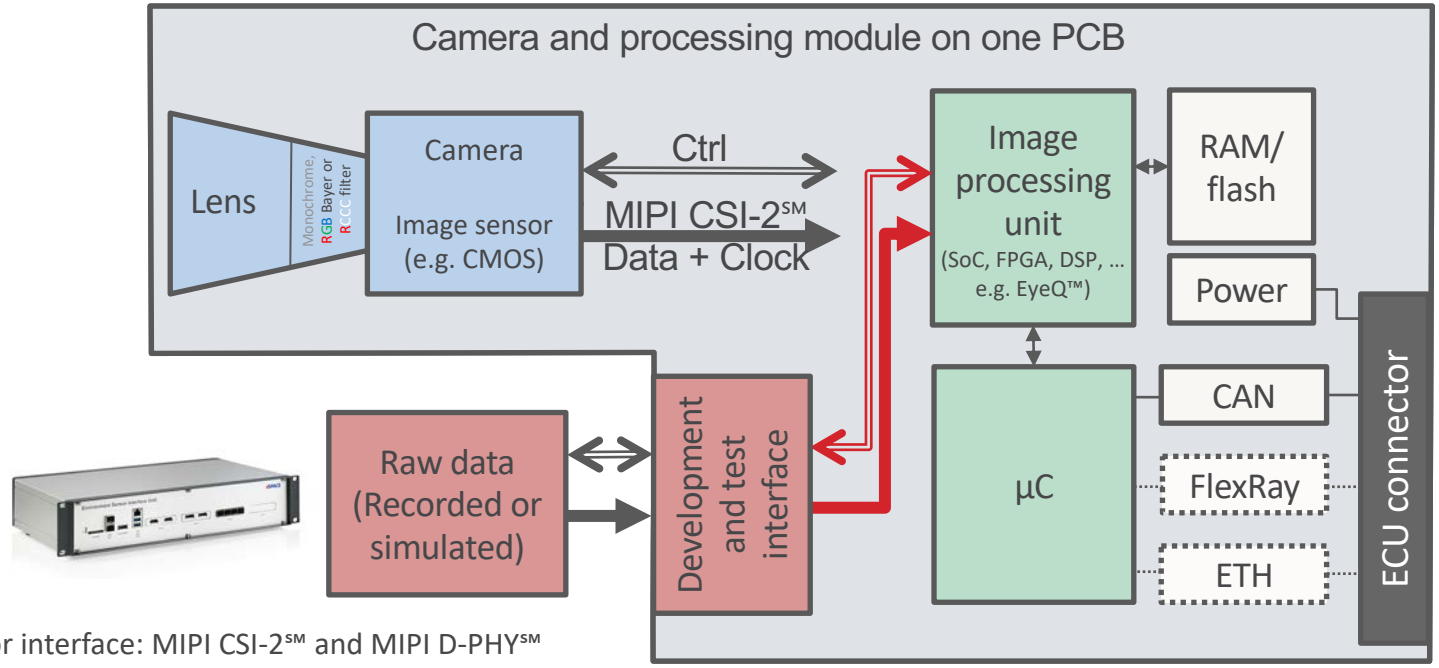
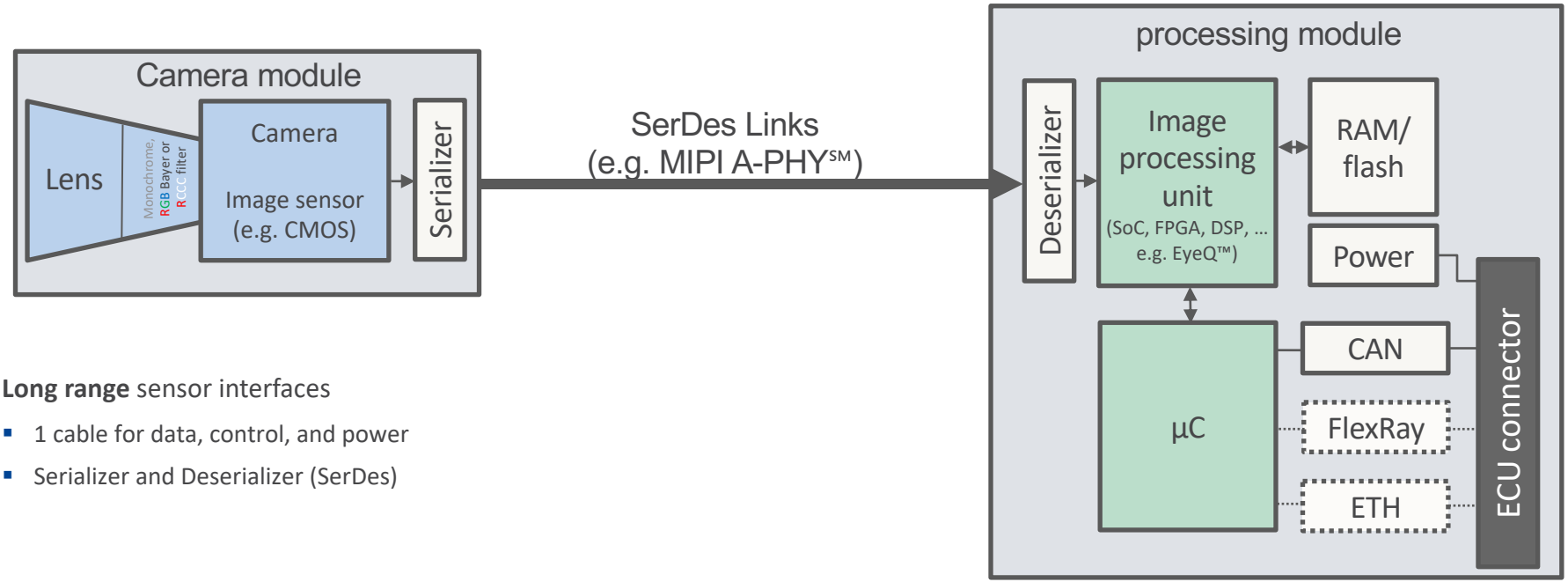
Front Camera: Hardware in the Loop testing



- **Short range** sensor interface: MIPI CSI-2℠ and MIPI D-PHY℠
- Test system simulates the sensor
  - MIPI CSI-2℠ data stream incl. timing
  - Sensor control interface (e.g. I2C)

Surround View Camera: HIL testing



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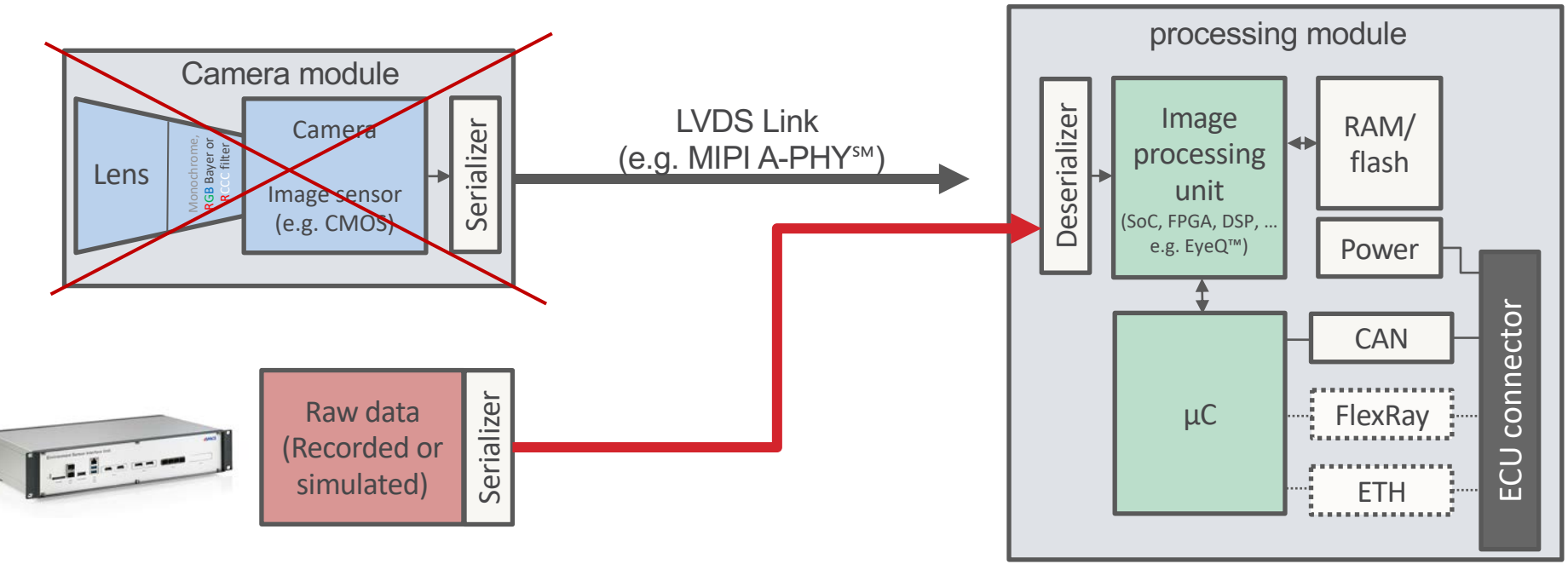
Surround View Camera: HIL testing



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Virtual Test Drives – Recorded Sensor Data

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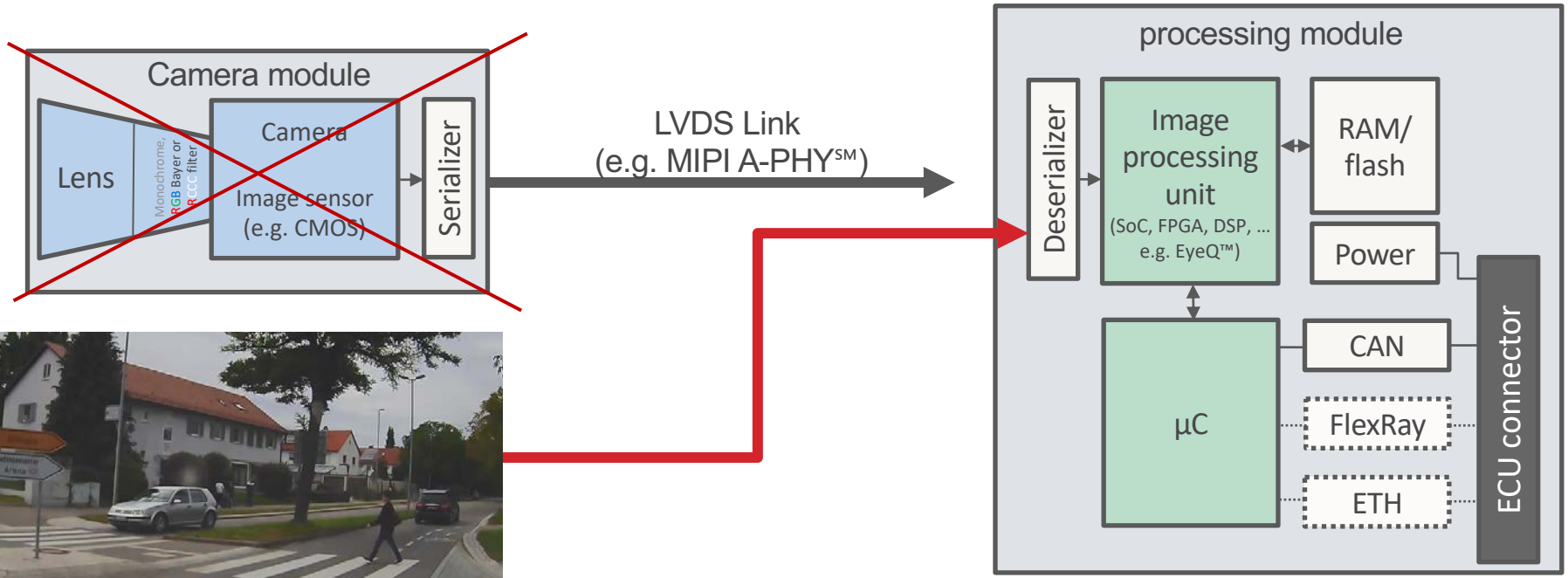
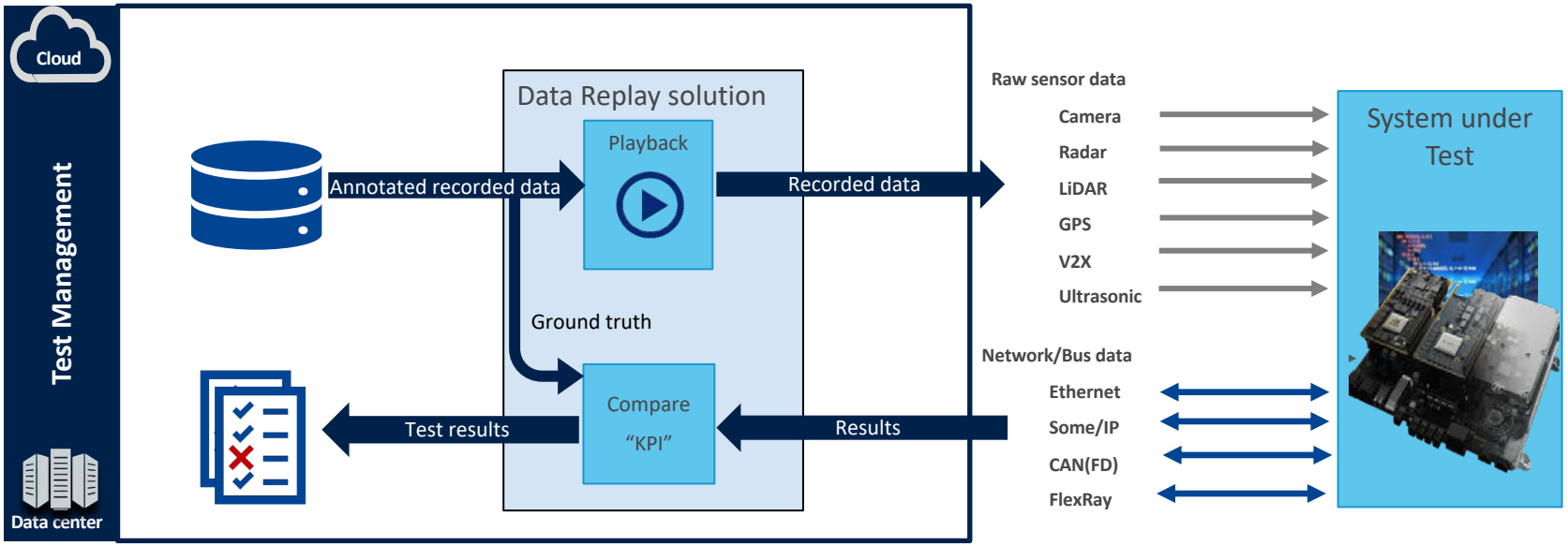
Virtual Test Drives – Recorded Sensor Data

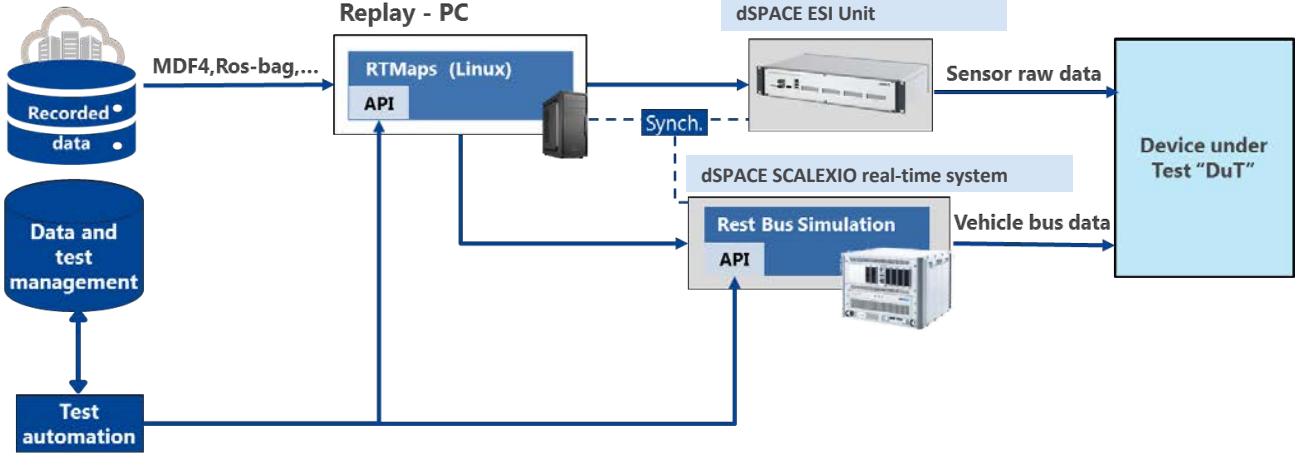


Sensor Data Replay HIL



Sensor Data Replay HIL

Sensor fusion and environment perception tests



Key takeaways

- Test sensor components and ADAS/AD platforms
- High quality data synchronization through gPTP
- Modular solution to fit variant bandwidth
- Flexible adaption of sensor interfaces via plug-in modules e.g. MIPI CSI-2℠, LVDS, …

gPTP: generalized precision time protocol

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Virtual Test Drives – Simulated Sensor Data

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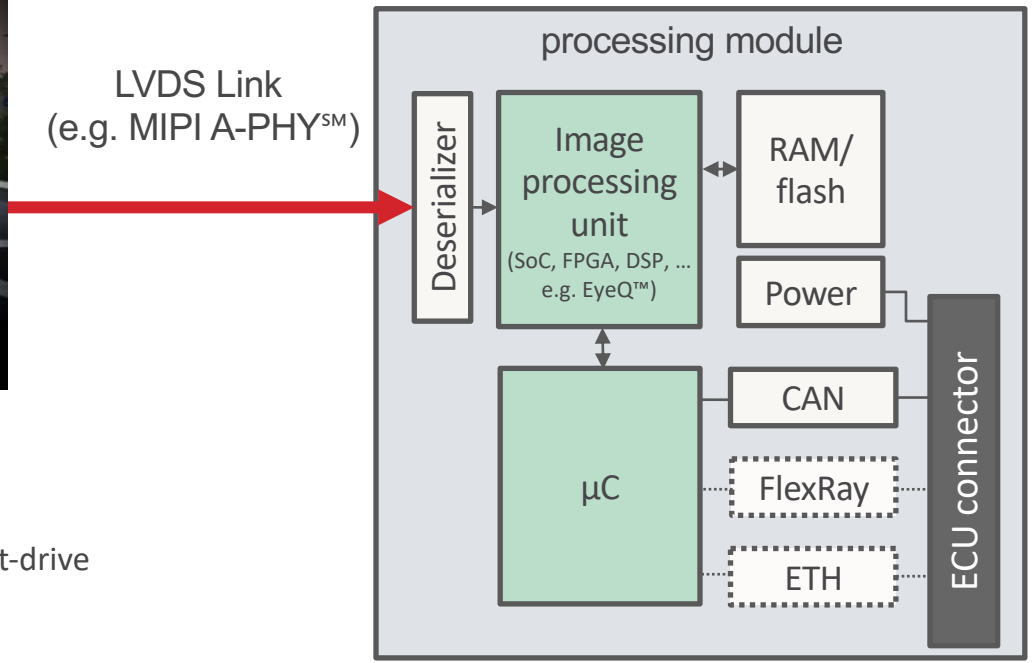
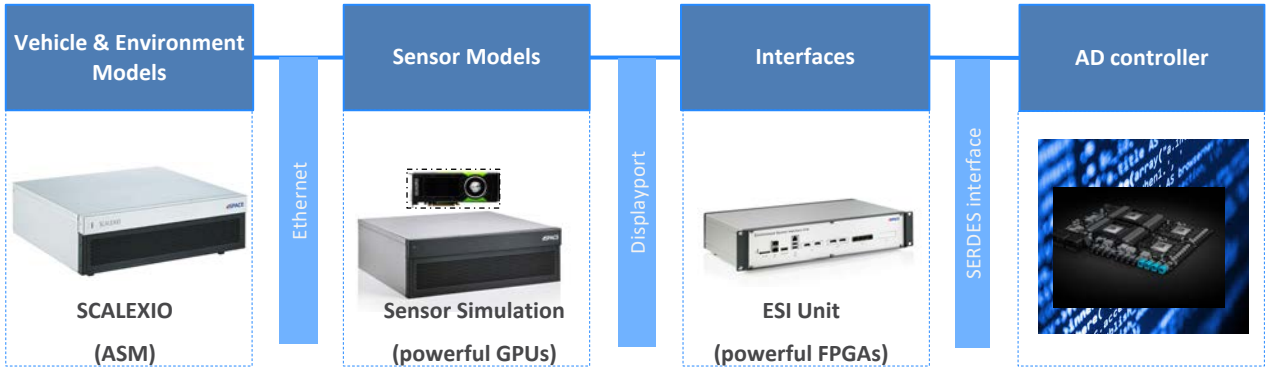
Virtual Test Drives – Simulated Sensor Data



- Simulated traffic scenarios
  - Testing relevant **corner-cases**
  - Thousands of different scenarios based on one test-drive
  - Change, e.g., weather, # pedestrians, etc.
- Closed-loop simulation

Simulation of ADAS/AD Sensors

dSPACE Sensor Simulation HIL

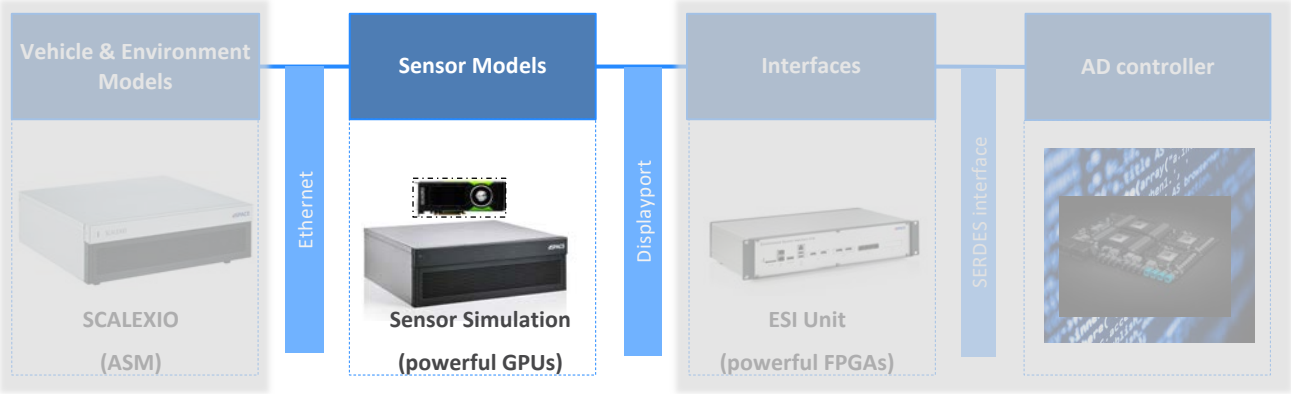


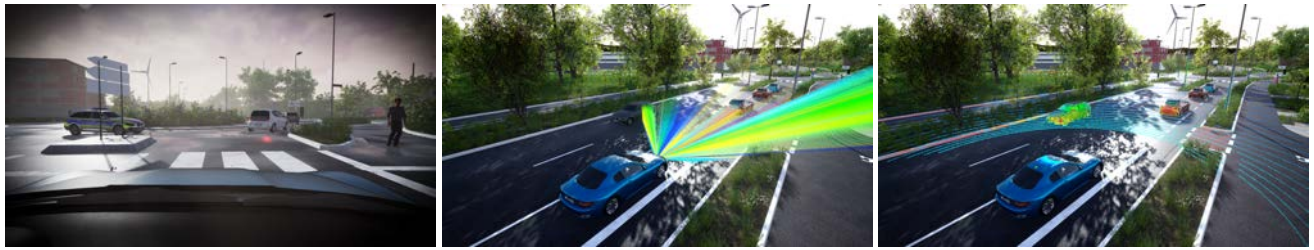
Key takeaways

- **Vehicle & Environment Models**
  - Running in hard real-time
- **Camera Sensor Model** on GPU
  - Lens simulation
  - Bayer Pattern Simulation
- FPGA provides **SERDES sensor interfaces**
- **Camera Sensor Model** on FPGA

Simulation of ADAS/AD Sensors - GPU

GPU-based Camera Simulation





Key takeaways

Challenges

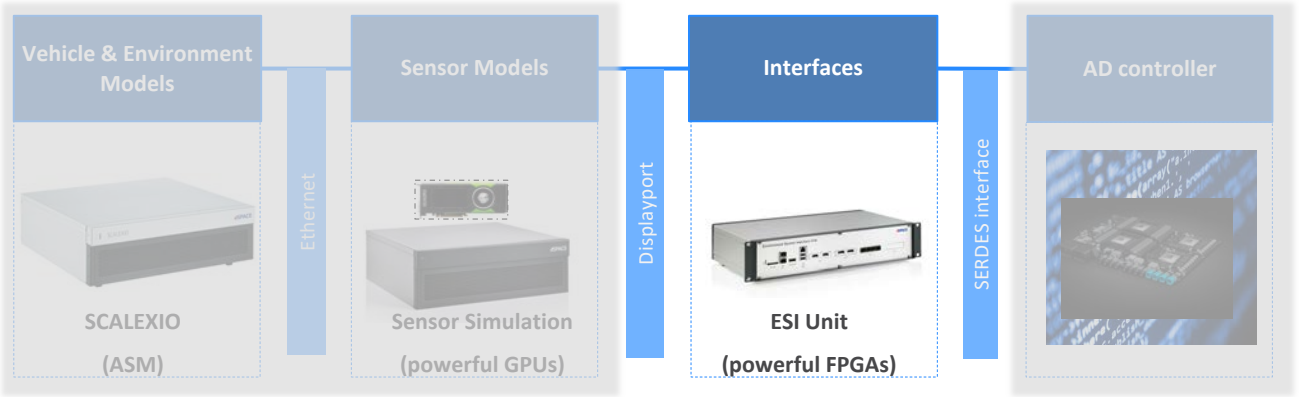
- Verification of sophisticated AI algorithms for AD
- ISO 26262 ASIL checks

Solution

- Accurate and verified sensor models for **Camera, Radar, Lidar**
  - Ray tracing
  - Weather simulation
  - Lens simulation
- **Open standard** for sensor simulation
  - OpenSimulationInterface (OSI)
  - OpenDrive, OpenScenario

Simulation of ADAS/AD Sensors – ESI Unit

dSPACE Sensor Simulation HIL

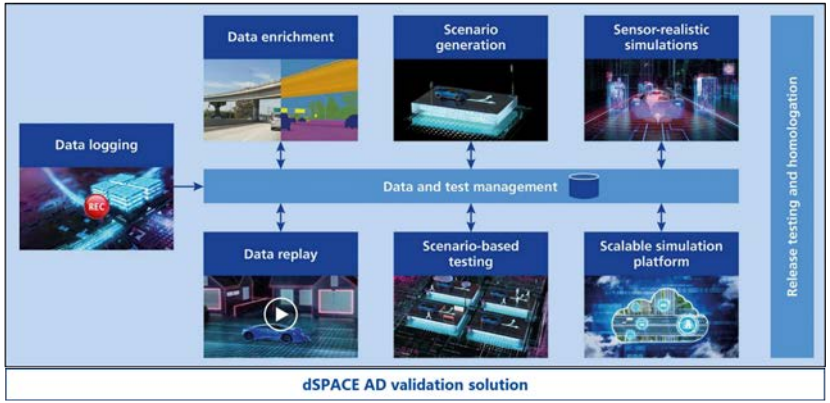


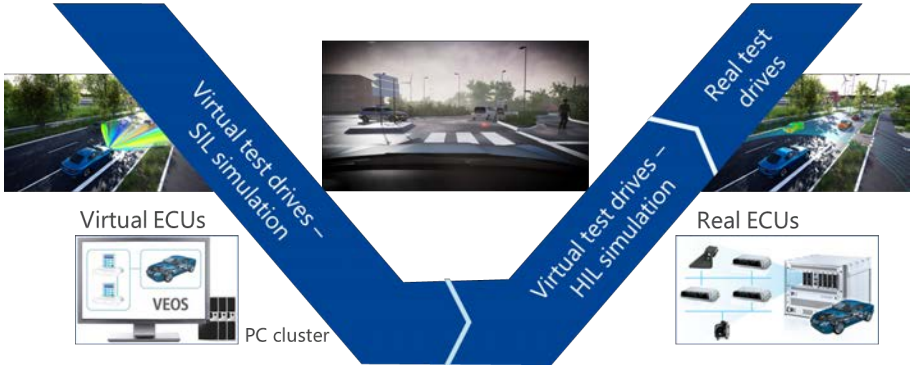
Key takeaways

- Support for **all** relevant **sensor interfaces** (Up to 10 Gbit/s)
- Raw data simulation for **Camera, Radar, and Lidar**
- FPGA-based **sensor models**
  - E.g., I2C simulation
- Up to **50 Gbit/s** aggregated data rate per ESI Unit
- Synchronous simulate of up to **12 sensors** per ESI Unit
- Synchronization of multiple ESI Units and SCALEXIO

Conclusion

Data-driven development and validation





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