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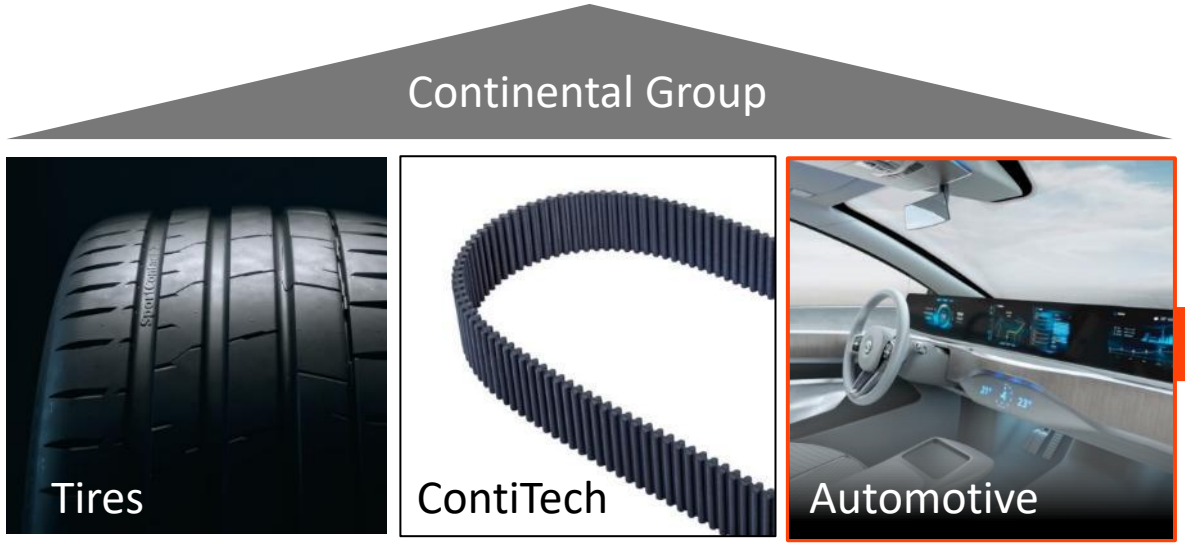
A Decade of Automotive Camera Technology

Product Line Camera – Dr. Martin Punke
Autonomous Mobility

November 26th. 2025

New company: AUMOVIO
Result of Continental group sector Automotive spin-off



Continental AG

Aumovio SE

- New founded, **independent** company.
- Business structure, expertise and portfolio of former Continental group sector Automotive stays the same.

AUMOVIO’s business areas
Home of our expertise

Autonomous Mobility (AM)

Pioneering the autonomous future

Architecture and Network Solutions (ANS)

Enabler of value driven architectures

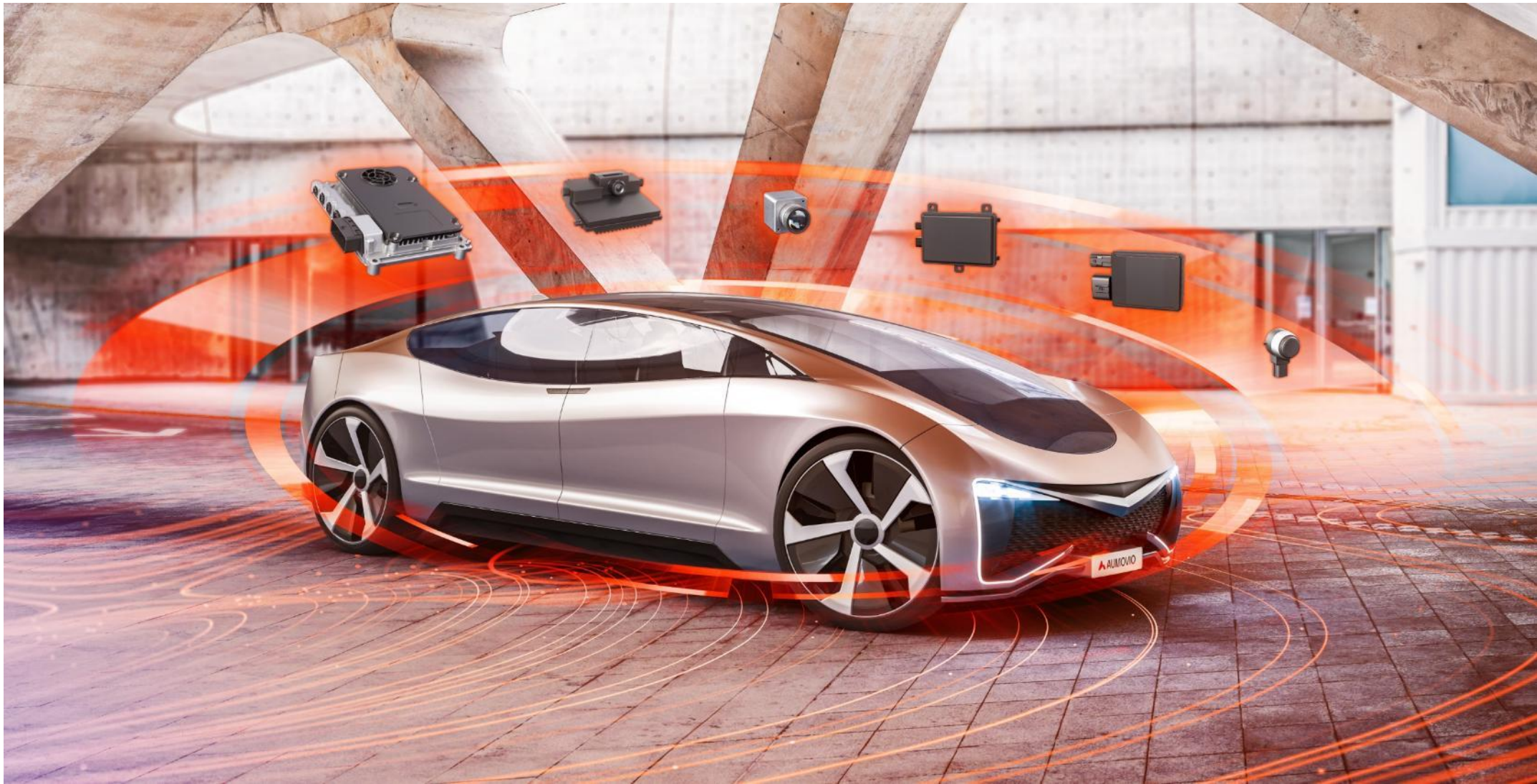
Safety and Motion (SAM)

Efficient safety powerhouse

User Experience (UX)

The exciting differentiator

Autonomous Mobility
Product Portfolio



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Agenda

The future (ten years ago)

Automotive market

System architecture

Camera hardware
(Optics, image sensors)

The future (in ten years)

The future (ten years ago)

Automated driving for accident-free driving
Roadmap & History

From 2015 presentation

- ACC Longitudinal/Lateral
- Traffic Jam Assistant (highway)
- Lateral Collision Avoidance
- Emergency Steering Assistant

AEB City < 50 kph

Parking Assist

2015-2016

Driver Distraction

AEB Pedestrian

Construction Site Assist

Remote parking

AEB > 60 kph

Automated Parking

Highway Assist Stop&Go, Cruising, 0-130km/h

Construction Site (high-automated)

Inter-Urban

City Stop&Go

Highway (high automated)

Autonomous

Partially Automated (2016) – Highly Automated (2020) – Fully Automated (> 2025)

2015 2020 > 2025

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From robotaxis to robotrucks

Von Grendelkhan - CC BY-SA 4.0

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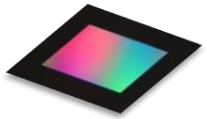
Automotive market

Automotive market

Market players – 10 years ago

Tier 2
Components

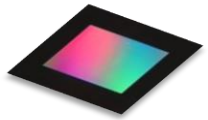


Tier 1
Sensors / Systems

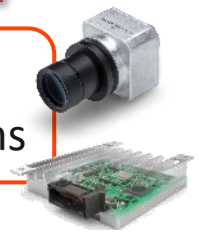
Car manufacturer

Automotive market
Market players – today

Tier 2
Components



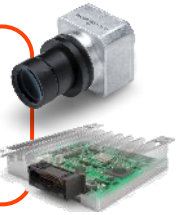
Tier 1
Sensors / Systems



Former Tier 2
Sensors

Tier 1
SoC / CV stack

Tier 1/2
Components /
Sensors / SoC



Car manufacturer

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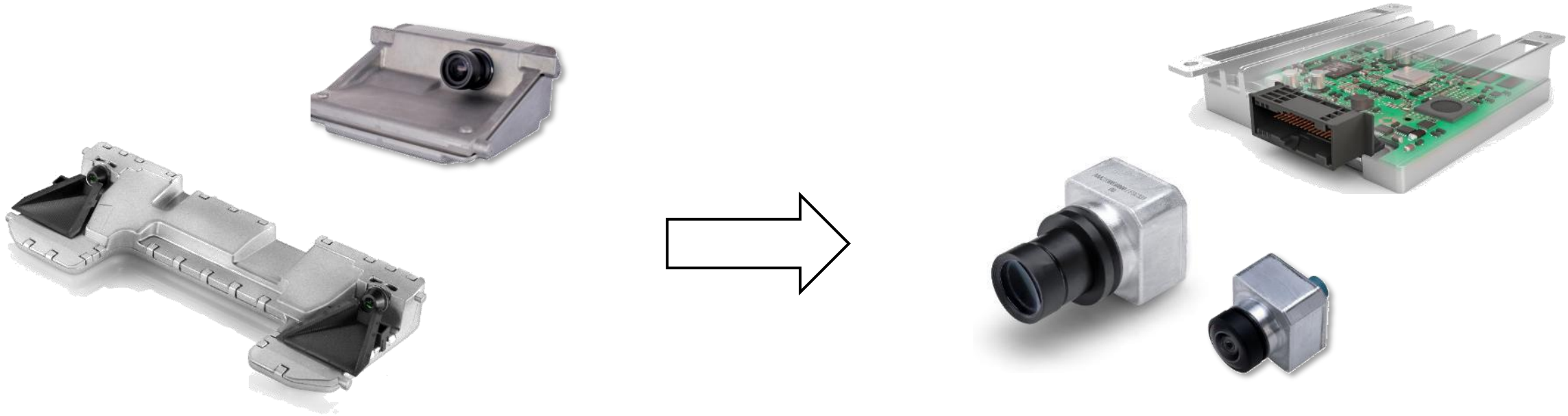
System architecture

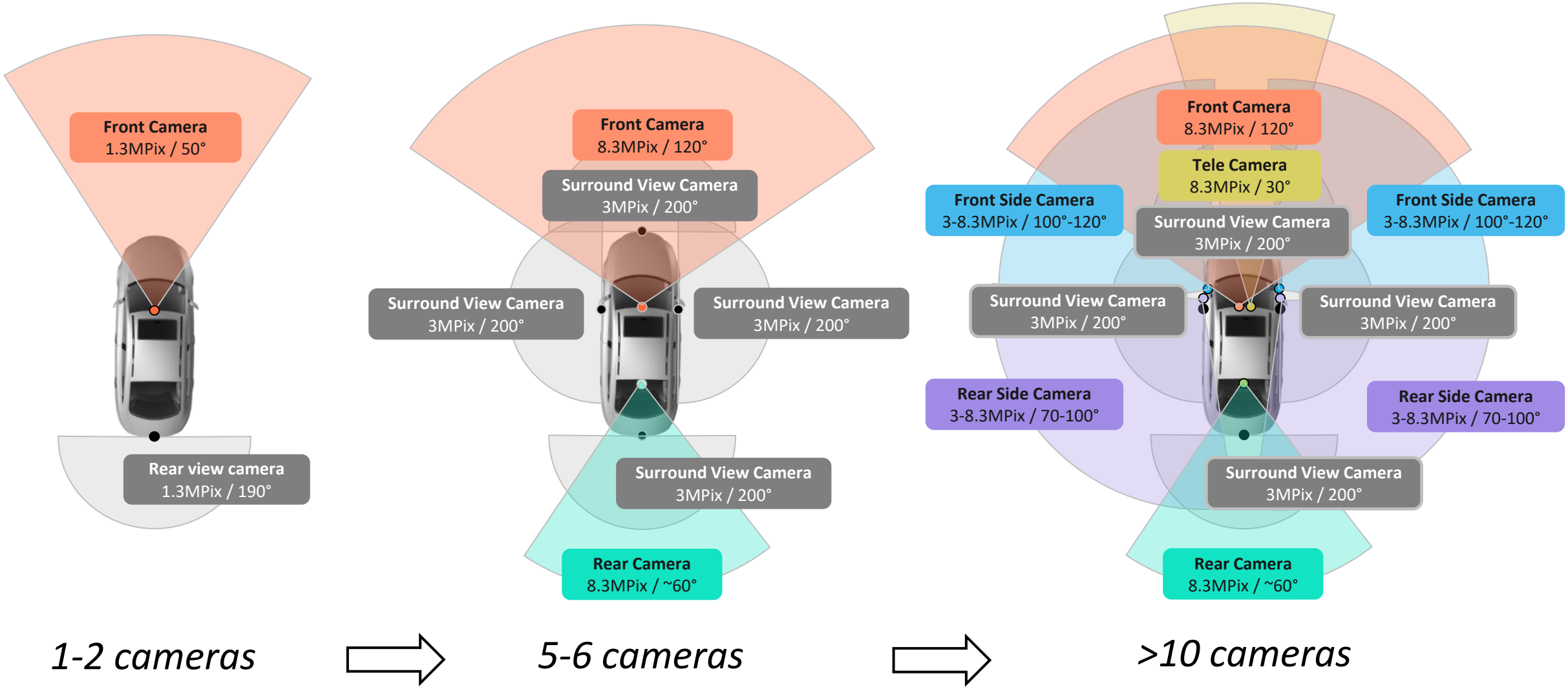
System architecture
From smart cameras to satellite cameras



There is a clear trend moving from smart cameras towards satellite cameras for higher SAE level systems.

System architecture

From single cameras to multi-camera setups



1-2 cameras ⇨ *5-6 cameras* ⇨ *>10 cameras*

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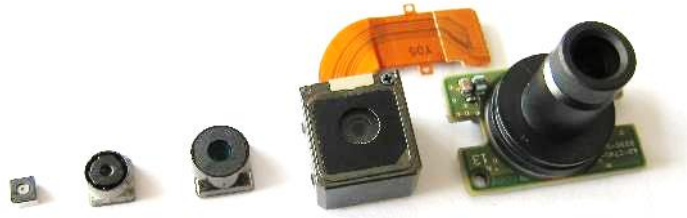
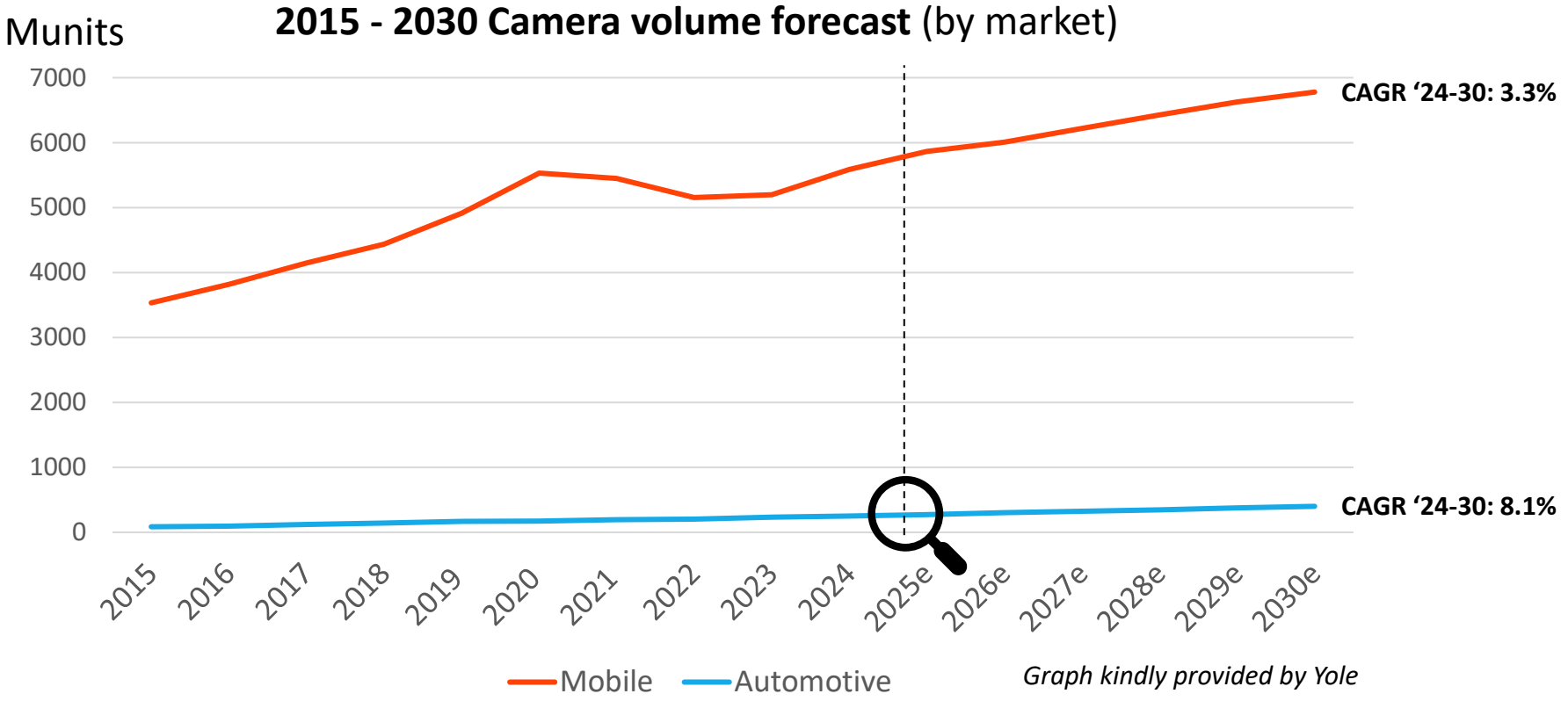
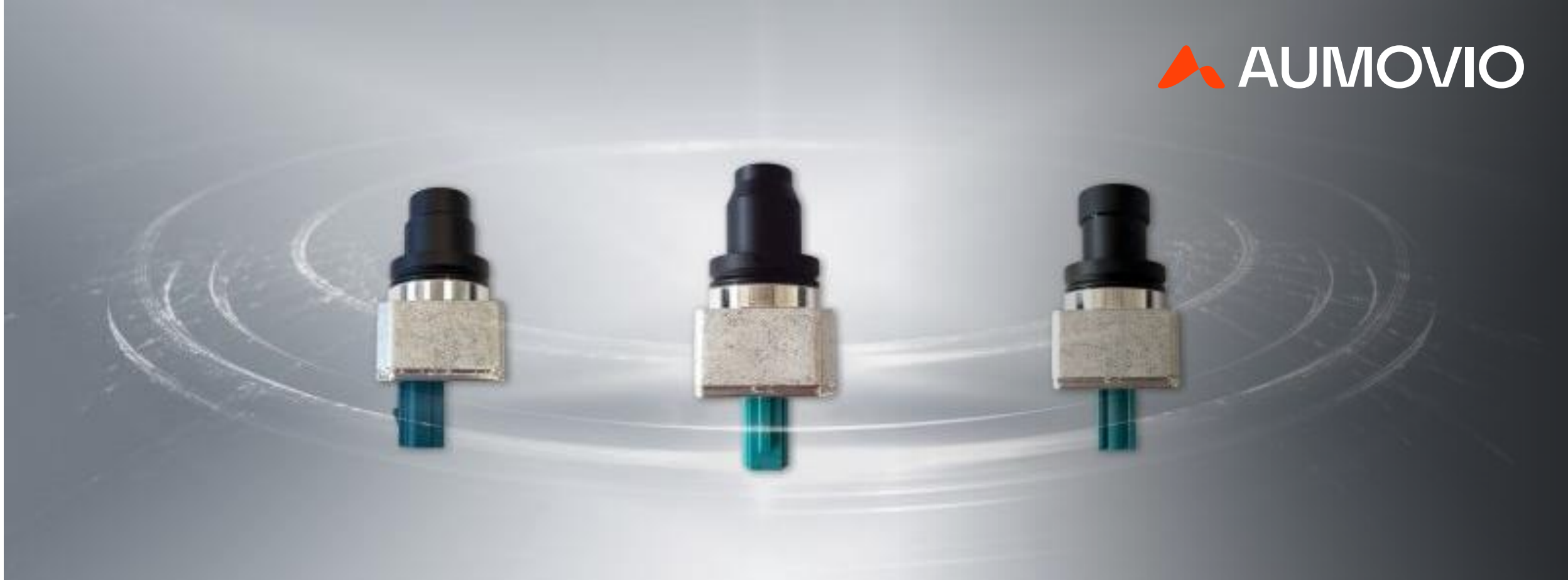
System architecture
Camera module volume





Automotive: more cameras than in a smartphone; but overall volumes remain smaller.

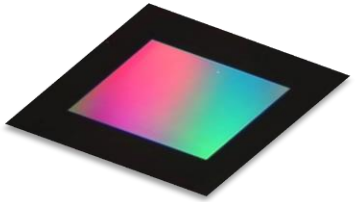


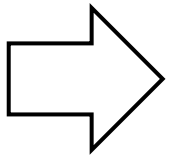
Camera systems

Camera systems
Hardware blocks

Camera module

Camera processing





Camera optics

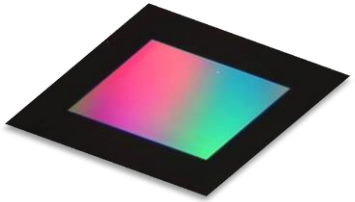
Image sensor

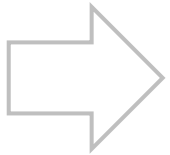
System on chip (SOC)

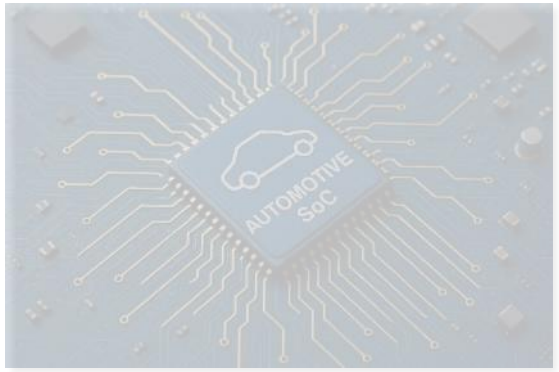
Camera systems
Hardware blocks

Camera module

Camera processing



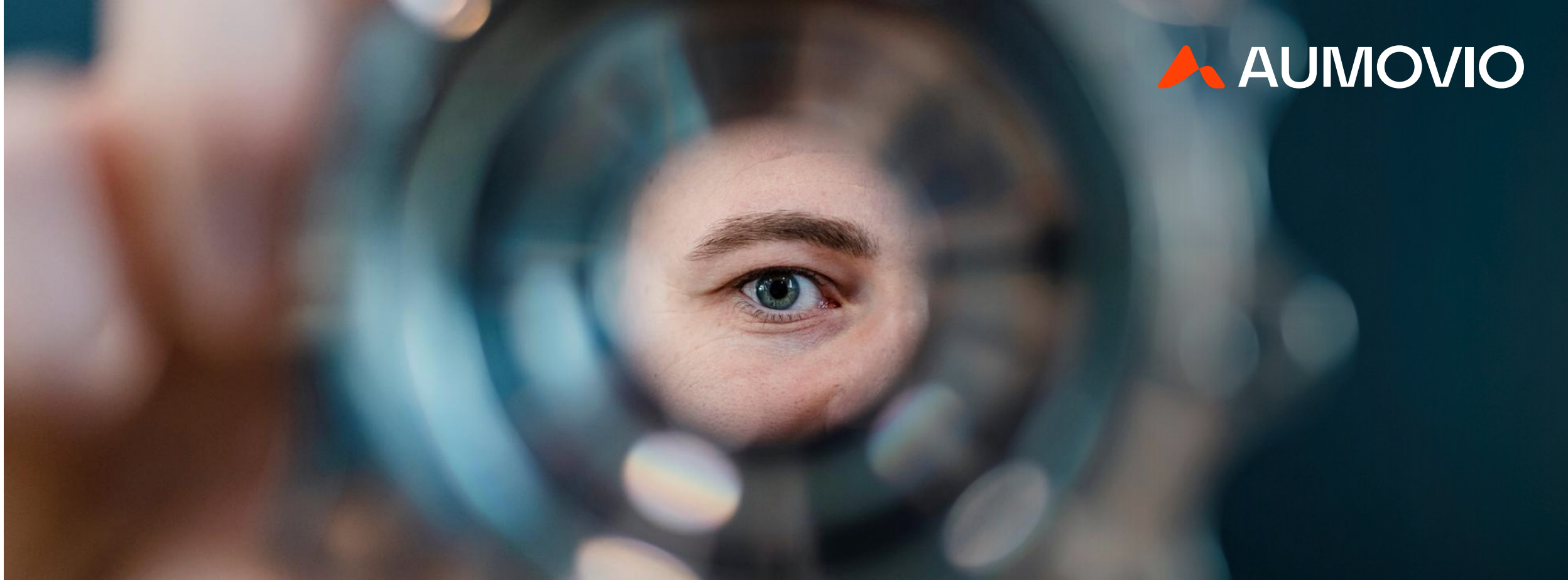




Camera optics

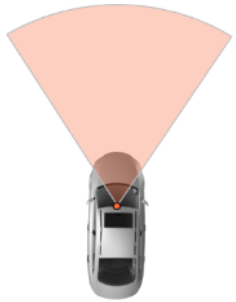
Image sensor

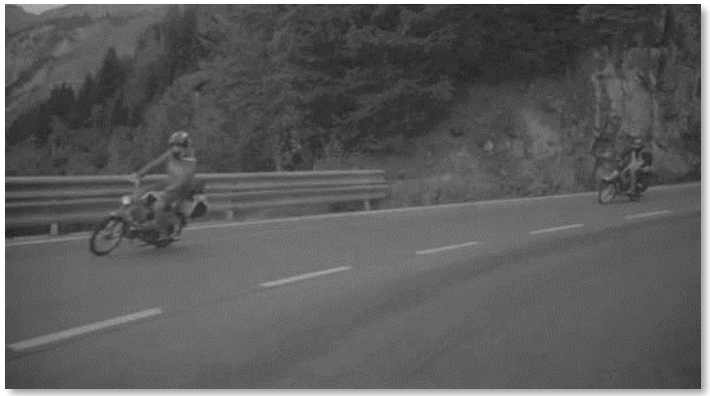
System on chip (SOC)



Optics

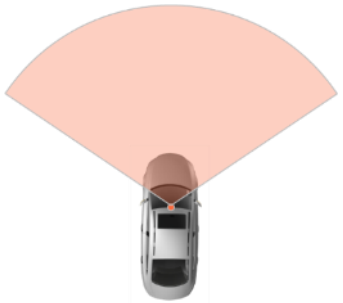
Camera optics
Functionality evolution





Camera with small FoV

Camera with large FoV



- Higher FoV (field of view) for front camera (50° → 120°)
- Multiple FoVs for different applications (tele, side, rear….)
- Variable distortion lenses (center/corner focused)

2015 → 1 front / 1 rear lens

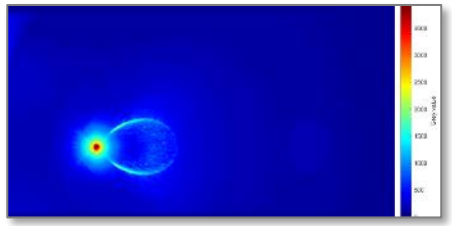
2025 → > 20 variants

Camera optics variation exploded in recent years.

Camera optics
Performance evolution

Enabling technologies
- Full glass designs
- Introduction of glass aspheres
- Improved coating technology
- Automated assembly
- Enhanced simulation tools

Performance evolution
- Lenses for smaller pixels / higher resolution
- Low F# lenses
- Low straylight / minimal ghosting
- Best possible sharpness (MTF)
- Stable performance under all environmental conditions



Ghost test result

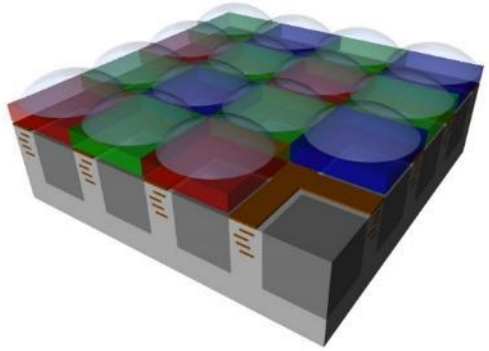
Real image

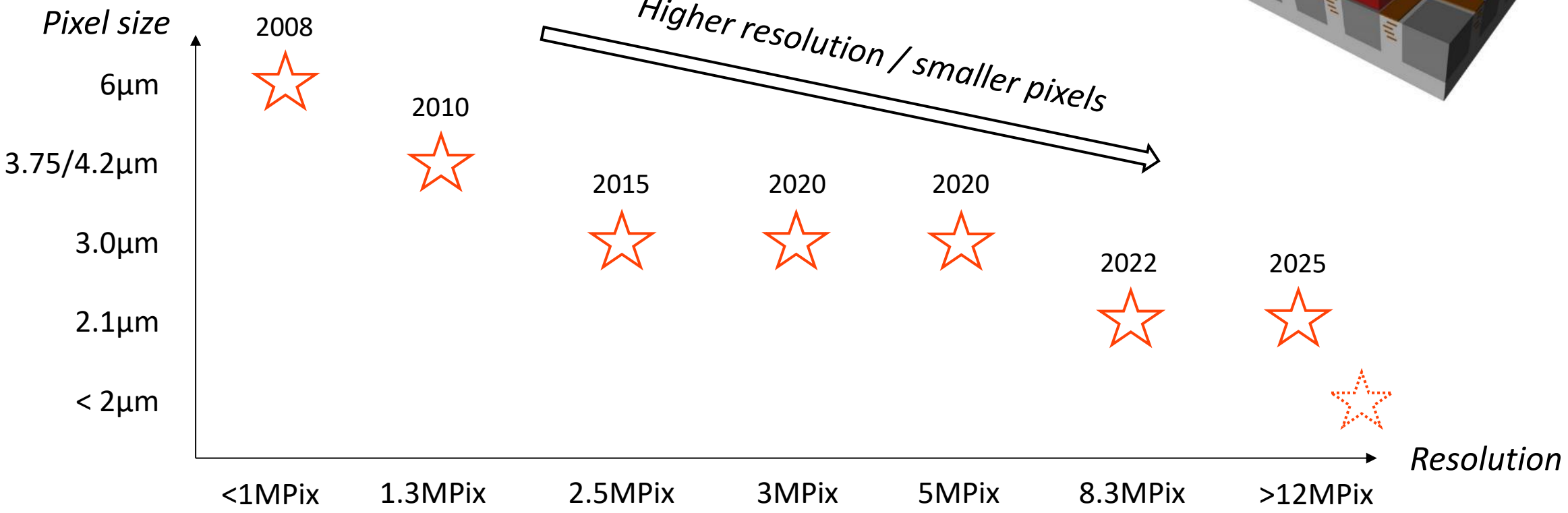
Surround view camera

Camera optics performance increased significantly over the past years;
now cost pressure leads to new designs (e.g., less glass molds, hybrid designs)

Image sensor

Image sensors
The megapixel race in automotive





Megapixel race slower than in mobile phone business but still existing.

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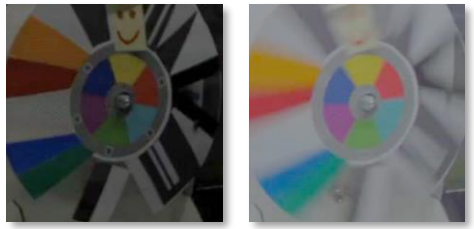
Image sensors
Technology

Enabling technologies

- Back-side illumination (BSI)
- Stacked sensors with smaller logic die process nodes
- Advanced HDR schemes: Multi-exposure / Dual-conversion gain / Split-Pixel
- Integration of capacitors for further dynamic range enhancement

Functional evolution

- LED flicker mitigation
- Functional safety: ASIL B/C support
- Cybersecurity functionality
- Integrated Image Signal Processor (ISP)



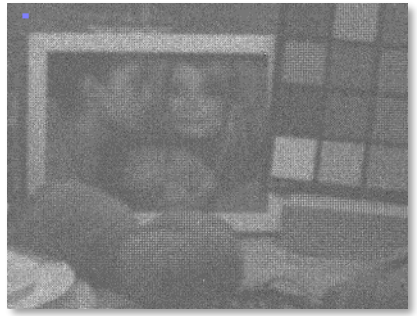
Fundamental trade-off between
long integration times (low-light; flicker mitigation) and motion blur not fully solved yet.

Image sensors
Technology

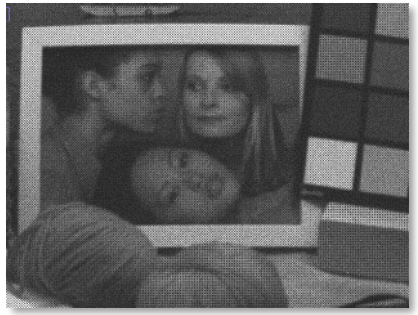
Performance evolution

- SNR improvements
  - Low-light performance
  - SNR over dynamic range
  - SNR over temperature

- Dynamic range improvements
  - Multi exposure
  - Single exposure

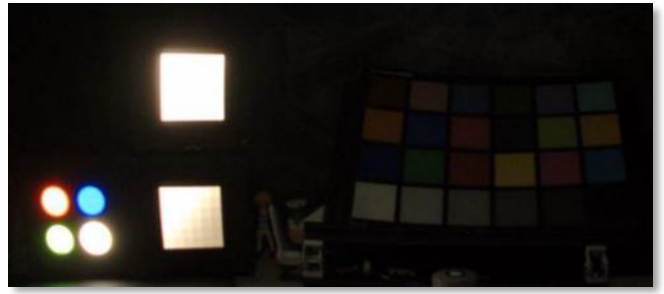


Older generation image sensor



Newer generation image sensor

High-dynamic range scenario



High-dynamic range test scene

2015 *< 80 dB*

2020 *120 dB*

2025 *140 dB*

Great improvements in image sensor functionality and performance over the years.

The future

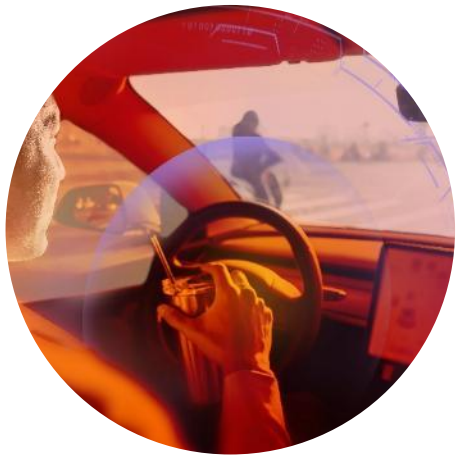
Future camera systems
Requirements

Night / all weather sensitivity for ADAS and AD
Improved performance of standard cameras
New sensor modalities (e.g., infrared, event-based)

Higher availability
Cleaning / heating solutions

Improved computer vision
More processing power
Realistic sensor modelling
AI based perception and scene understanding

Lower Cost
Material/manufacturing cost improvements
Optimized sensor setups



Future camera systems
Market trends

Geopolitical tensions
More regional markets (US, Europe, China, Asia)

Different market speeds in EV adoption
System architecture influences (e.g. AD, SDV)

Ownership model changes
Robotaxis
Robotrucks

Non-automotive markets
Special vehicles (e.g. agriculture, mining)
Industrial (e.g. moving platforms)
Robotics (e.g. humanoid robots)
Defense

Thank you!

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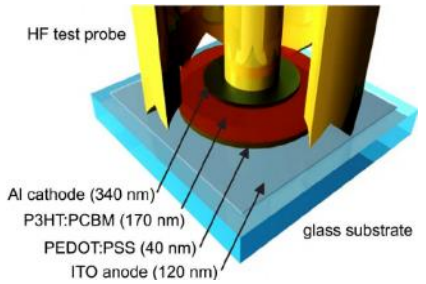
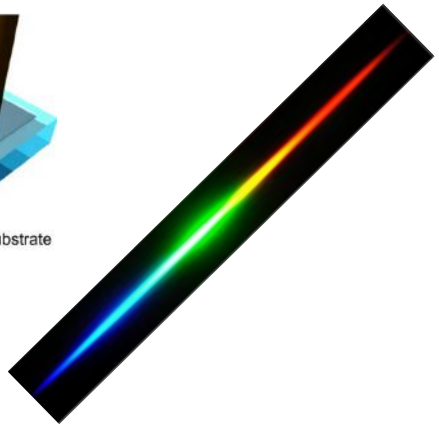
Biography
Martin Punke

- **Aumovio (former Continental) – 2012-today**
  - leading the Camera Product Technology group
  - concepting, engineering and productization of camera systems for ADAS applications with a focus on optics, image sensors and image quality
  - camera sensor modelling

- **Nokia Mobile Phones – 2007 - 2012:**
  - responsible of camera, flashlight and illumination technologies in mobile phones

- **University of Karlsruhe – 1997-2007:**
  - Ph.D. thesis on organic semiconductor devices for microoptical applications
  - Master thesis on femtosecond white-light pump-probe spectroscopy





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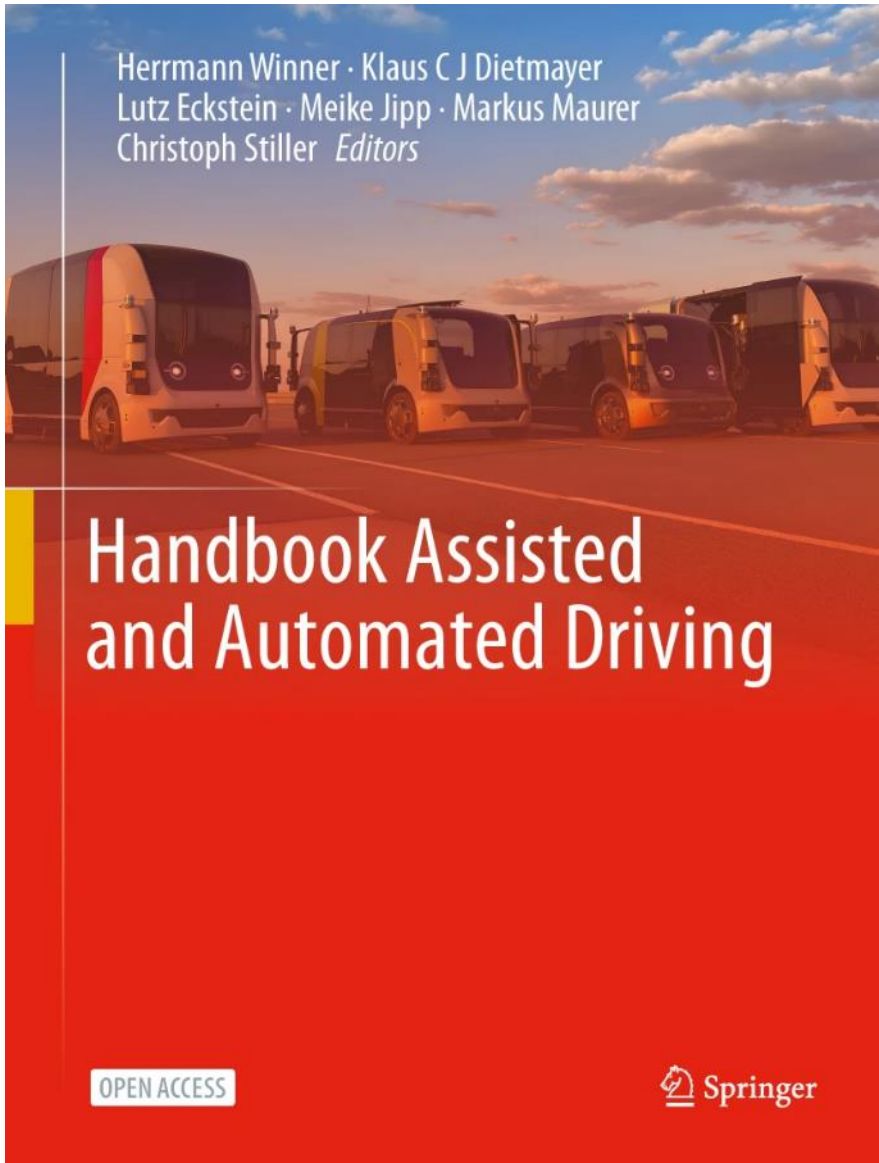
Publications
Handbook Assisted and Automated Driving

- Contributed with chapter about „Camera sensors“
- Hardcover available from January 2026
- Open online access from January 2026:
  - https://link.springer.com/book/9783658452759



Key takeaways and contact details

- The automotive camera business underwent major changes over the past decade.
- The camera technology and manufacturing saw great improvements.
- Cameras are nowadays a major part of every AD system and will further evolve.

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