PCI Express® Technology: Accelerating Automotive Connectivity, from Infotainment to ADAS

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PCI Express® Technology: Accelerating Automotive Connectivity, from Infotainment to ADAS

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Topics

- Automotive Trends and Implications for SoC Design
- New Automotive SoC Segments
- PCIe® in Automotive Applications
- Use Cases
- Examples of Commercial Chips
- Summary

Automotive Trends and Implications

Major Forces Shaping the Automotive Industry

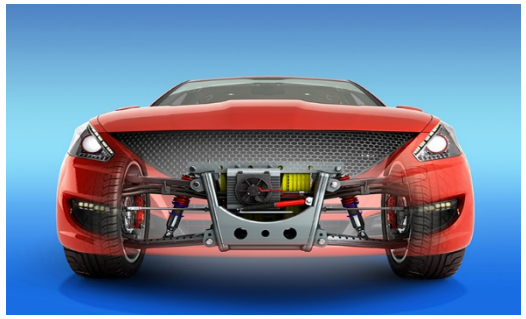
Growth of Autonomous Driving

- ADAS deployment
- Level 3 in 2019
- Level 4 by 2020~2025
- Security challenges

Increased Connectivity

- Multiple connectivity Telematics services
- V2X (4G/LTE → 5G)

Vehicle Electrification



Some barriers
- High battery costs
- Proliferation of charging infrastructure
- Wireless charging

Shared Mobility

Aka smart sharing

- Uber
- Lyft,
- Turo, etc.

Major Forces Shaping the Automotive Industry

Growth of Autonomous Driving

- ADAS depl
- Level 3
- Leve 025
- S nges

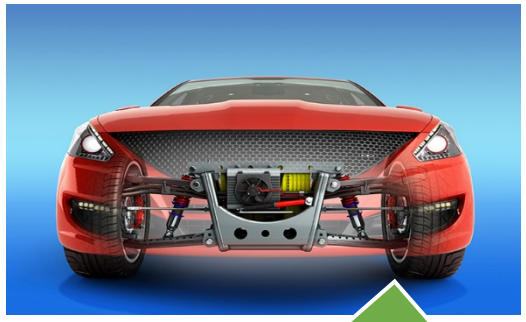
Broad Level 2 deployment

Increased Connectivity

- Multiple c
  Telema
- V2X)

Some clarity on DSRC vs C-V2X

Vehicle Electrification



Some barriers
- High ba
- Prob arging
- W arging

3.1M WW in 2020
$100/kWh target

Shared Mobility

- Uber
- Lyft,
- Turo, etc

Long-term reliability

What Are These Trends Telling Us?

- New use cases
  - IVI, digital cockpit, DMS
  - ACC, AEB, ADAS, ADS
  - OTA, V2x . . .
- More chips, more integration, more custom
- Use of more advanced process nodes
  - 16nm, 7nm, 5nm . . .
- More compute intensive
  - Sensor fusion, DSP, AI
- More data
  - Collection, analysis, edge AI
- More software (a lot more)

- New architecture
  - Heterogeneous SoC
  - NoC (memory coherency)
  - MCU, domain and zonal transition (IVN)
- Higher speed memories
  - LPDDR5X, GDDR6, HBM2e
- Higher speed (connectivity) interfaces
  - PCIe® 3.0/4.0/5.0/6.0
- Larger storage
- More internet connectivity
  - Wi-Fi, 4G/5G, cellular v2x, DSRC
- More security

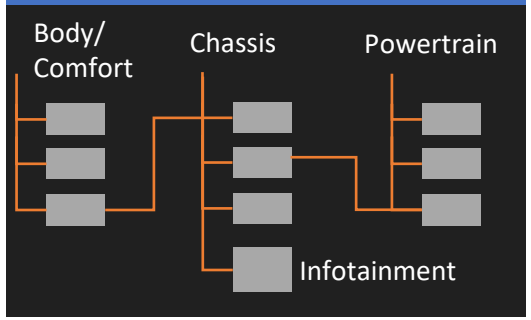
Automotive Market and Key Trends

Electrification Hybrid and EVs

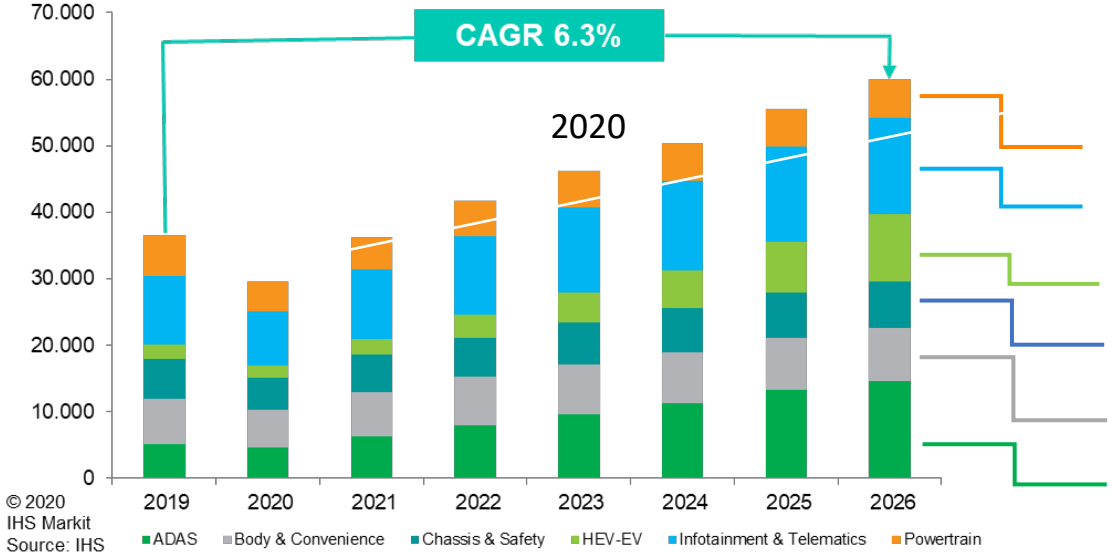
ADAS and Autonomous Driving

Infotainment and Connectivity

Zonal Architecture and ECU Consolidation



Auto Semiconductor Revenue by Domain ($M)



CAGR: 4.6% (2021) – Total semiconductor revenue

CAGR: 11.9% (2021) – Auto semiconductor revenue!

-1 % - Powertrain

5 % - Infotainment: Connectivity and Telematics

25 % - HEV-EV

2 % - Chassis and Safety

2 % - Body and Convenience

16 % - ADAS: Part. Camera, Radar, Lidar Sensors

New SoCs Adopting Advanced Process Nodes

Chassis, Powertrain, Body	Infotainment	ADAS	ADS
Active suspension, ABS, Engine control	Digital cockpit and driver monitoring	Advanced driver-assistance system (L1~L3)	Autonomous driving system (L4~L5)
Mature foundry process (90nm, 65nm, and specialty process)	Mature foundry process (28nm, 16nm → 7nm)	Advanced foundry process (16nm → 7nm)	Advanced foundry process (7nm → 5nm)

New Automotive SoC Segments

New Automotive SoC Segments

- Infotainment and digital cockpit (including driver monitoring)
- ADAS (sensor fusion – camera, radar, lidar, ultrasound)
- Autonomous driving (L4/L5, ML/AI)
- Telematics (Wi-Fi, BT, C-V2X, GPS)
- Cloud connectivity (OTA, e-commerce)

Infotainment SoC

- CPU
- GPU
- Audio Processing
- Video Processing
- LPDDR4/4X/5/5X
- MIPI D-PHY
- PCIe 3.0/4.0
- Flash I/F
- Q-SPI
- USB2/3

Table-stake IP in infotainment SoC

- Multi-core CPU
- GPU
- Advanced memory
- MIPI®
- PCIe® 3.0/4.0
- Storage interface
- USB2/3
- GbE

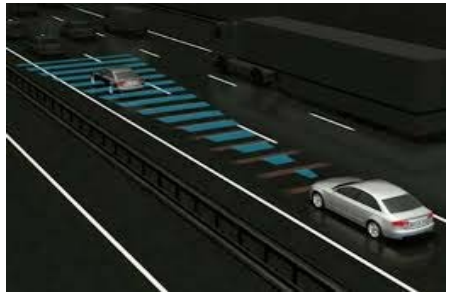
An infotainment chip looks very much like a ruggedized applications processor for smartphones!

From ADAS to Conditional Automation (Level 3)

Level 0

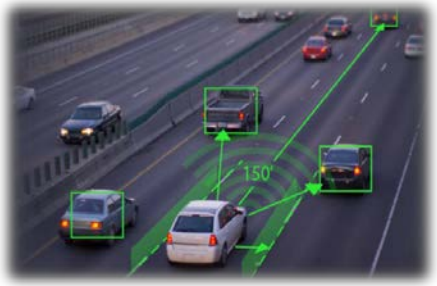
Level 1

Level 2



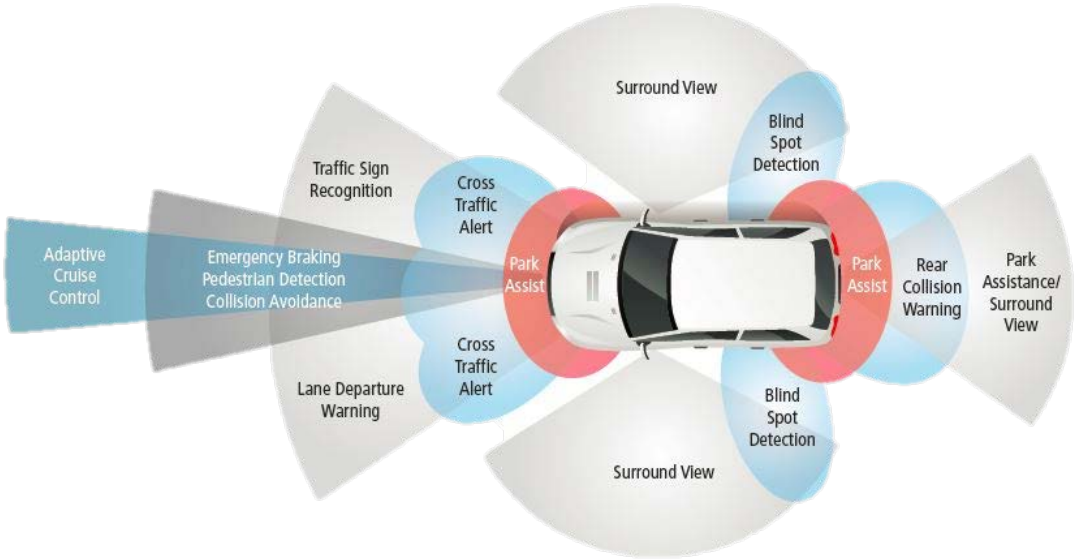
We Are Here!

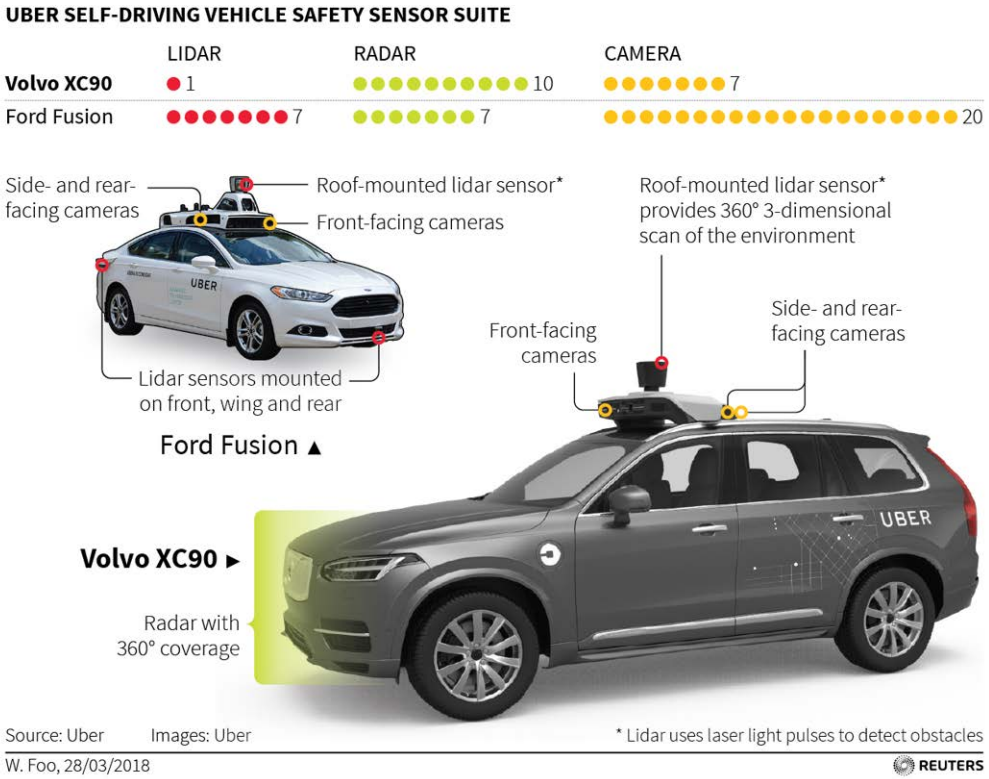
Level 3



Function	Manual Cruise Ctrl	Traffic Sign Detection	Adaptive Cruise Control	Highway Chaffeur
Features	Manual set of fixed speed No detection of environment	Camera-based traffic sign detection Manual control of speed	Camera-based traffic sign detection Automatic control of speed and distance	Lane keeping and change 360° surround view of traffic, driver monitoring Legal issues
Sensor/ECU	No sensors 1x ECU	1x front camera 1x ADAS ECU	1x front camera 1x front radar 1x ADAS ECU	2x front/rear cameras 1x front lidar 1x infrared camera 6x front/rear radars 1x gateway 1x sensor fusion ECU 1x GPS, IMU, DMS

Autonomous Vehicles – Supercomputer on Wheels

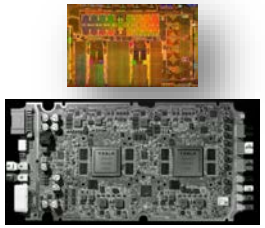




Evolution of Automated Driving Platforms

We Are Here!

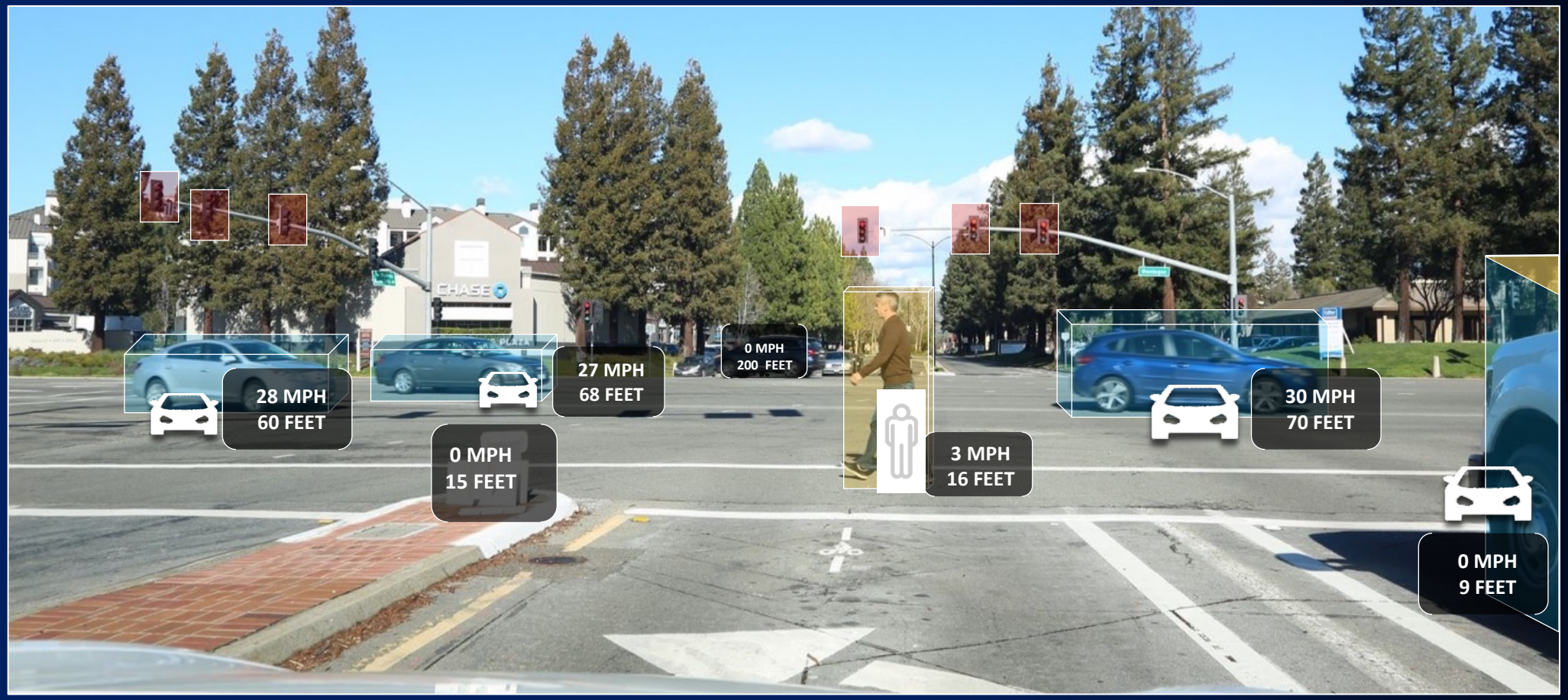
TOPS / Watt

0.25TOPS @ 2.5W	<1TOPS	20TOPS @ 250W	60TOPS	320TOPS @ 500W	144TOPS @ 72W
					

Mobileye	Audi	NVIDIA	Renesas	NVIDIA	Tesla
EyeQ3	zFAS	Drive PX2	R-Car V3U	Drive PX Pegasus	FSD Computer
Black box	Proprietary	Open system	Open system	Open system	Proprietary
Standard components	Standard components	Standard components	Standard components	Standard components	Proprietary SoC
HW + SW	HW	HW + ML env.	HW	HW + ML env.	HW + SW + ML env.
Air cooling	Air cooling	Water cooling	Air cooling	Water cooling	Air cooling

Source: Audi, Mobileye, NVIDIA, Renesas, Tesla

Perception from Vision, Radar, and Lidar Sensors Are Combined

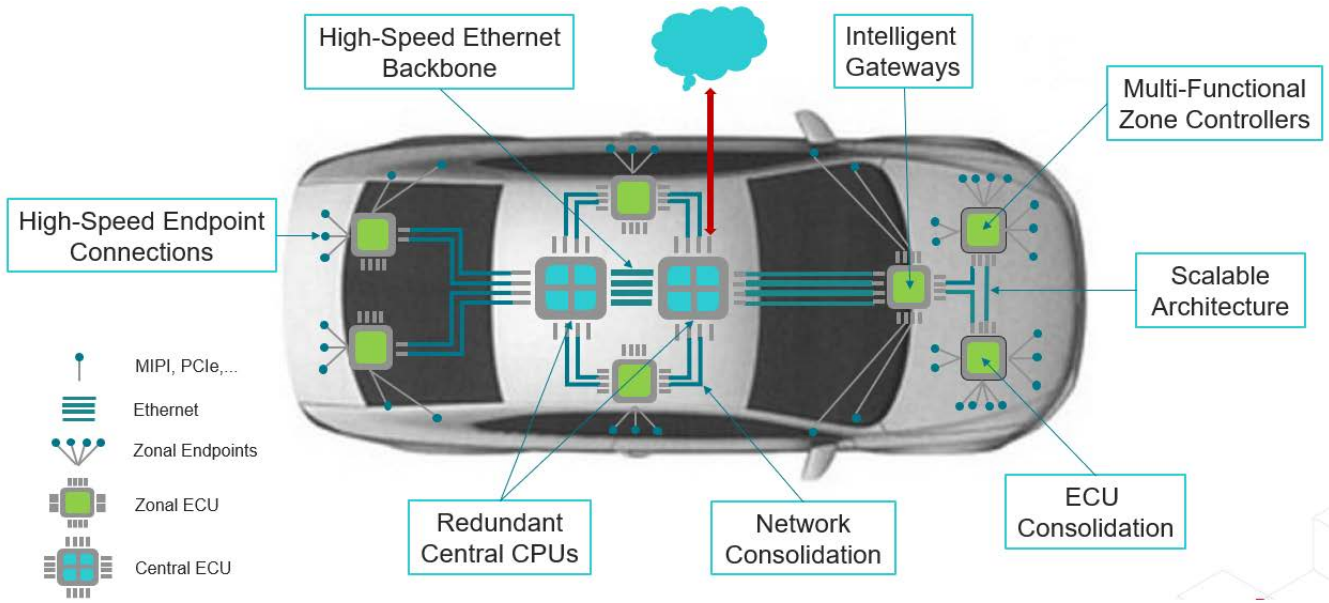


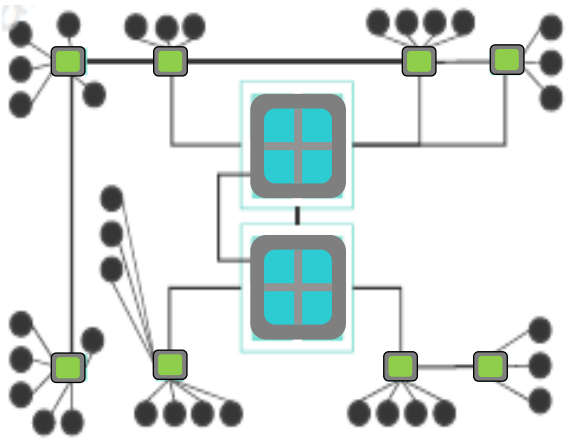
Vision
Radar
Lidar

AV Estimates Path of Surrounding Cars and Pedestrians

Path Planning

E/E Architecture Evolving to Domain and Zonal Network

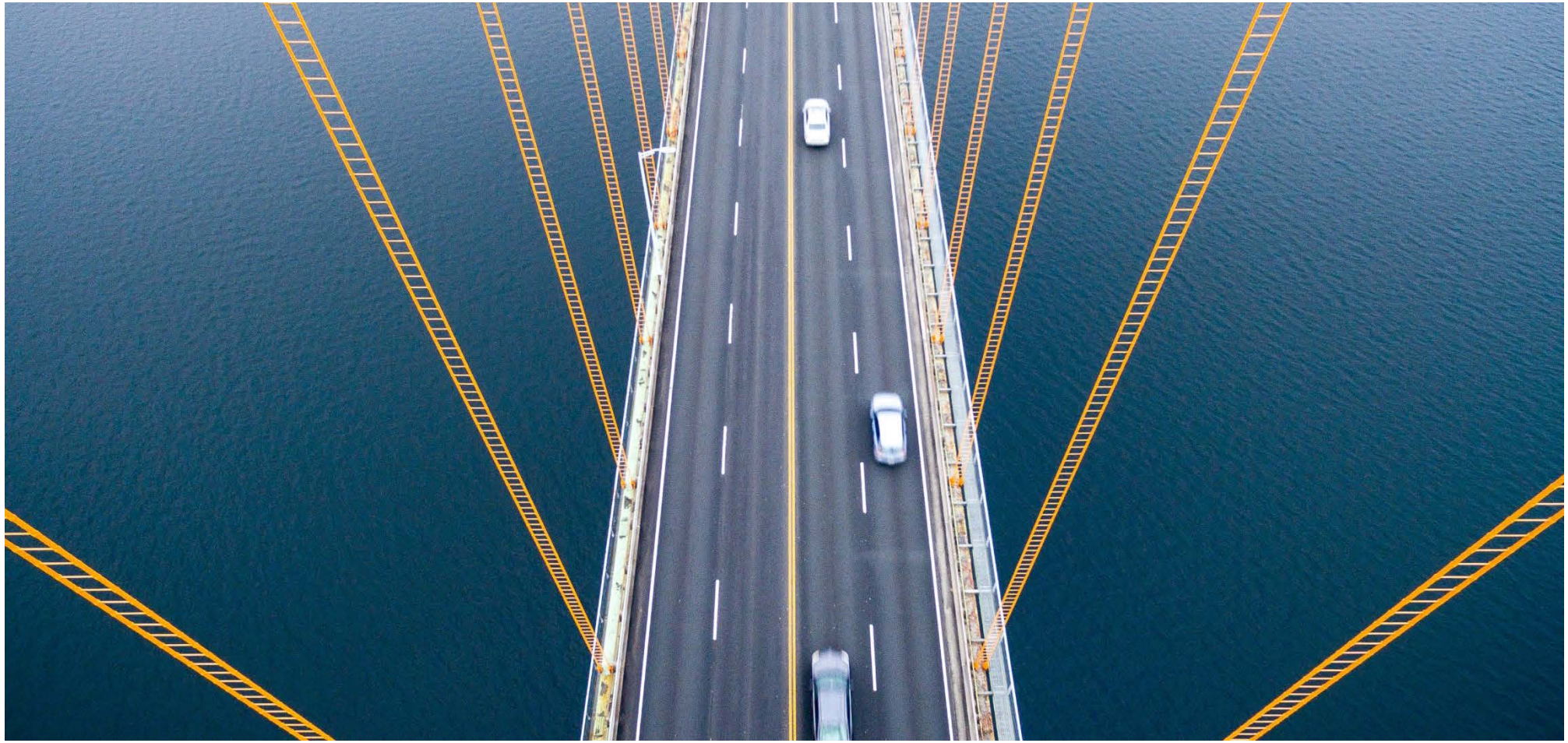




PCI Express® technology is mission critical in Domain and Zonal Network

- Already adopted in multiple generations of infotainment and ADAS SoC
- Key protocol in chip-to-chip communications, central processing and high-speed end point connections

PCI Express® Architecture in Automotive Applications



PCIe® Technology – A Ubiquitous Interface, Applied to Automotive

Empowering next generation of data intensive autonomous driving designs

Built on the state of the art 96-layer 3D NAND and leveraging the NVMe architecture to provide unmatched performance in automotive industry for years to come. The IX SN530 family is designed to support break through innovation development from the latest safety and driver assistance systems to autonomous driving.

https://www.westerndigital.com/products/commercial-internal-drives/automotive-ix-sn530-nvme-ssd

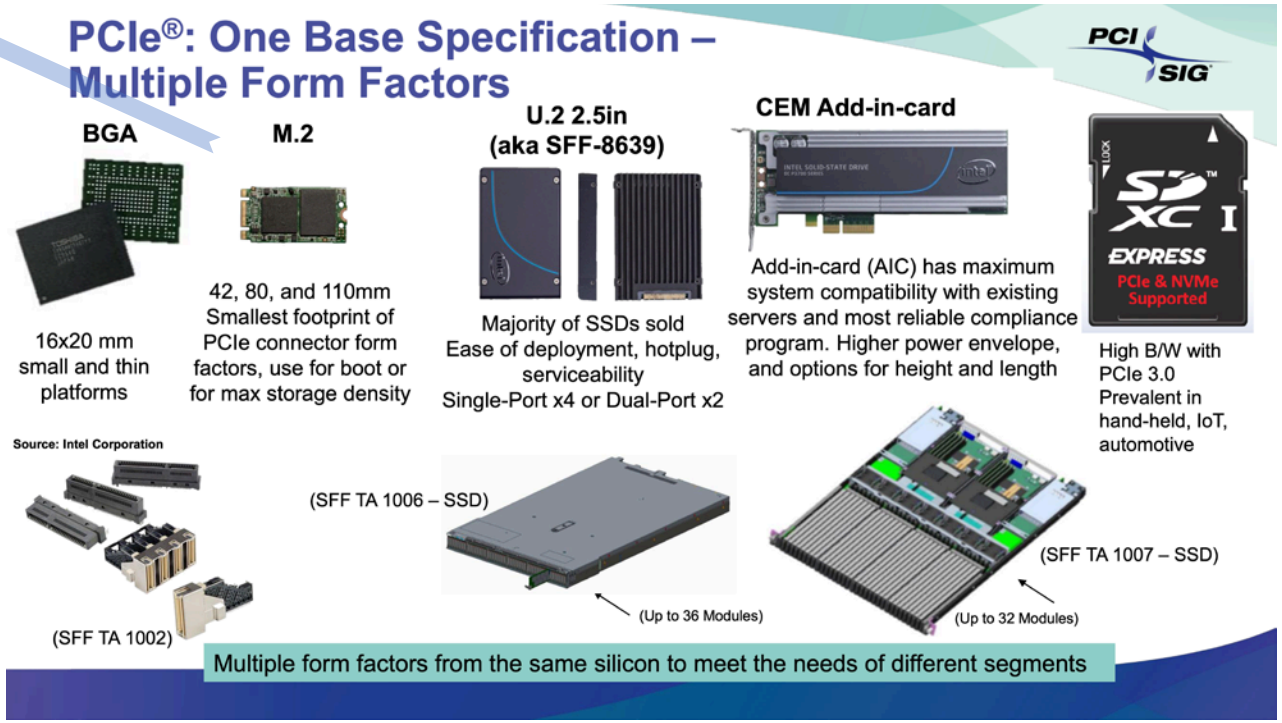
STORAGE

The Role of PCIe NVMe Industrial SSDs

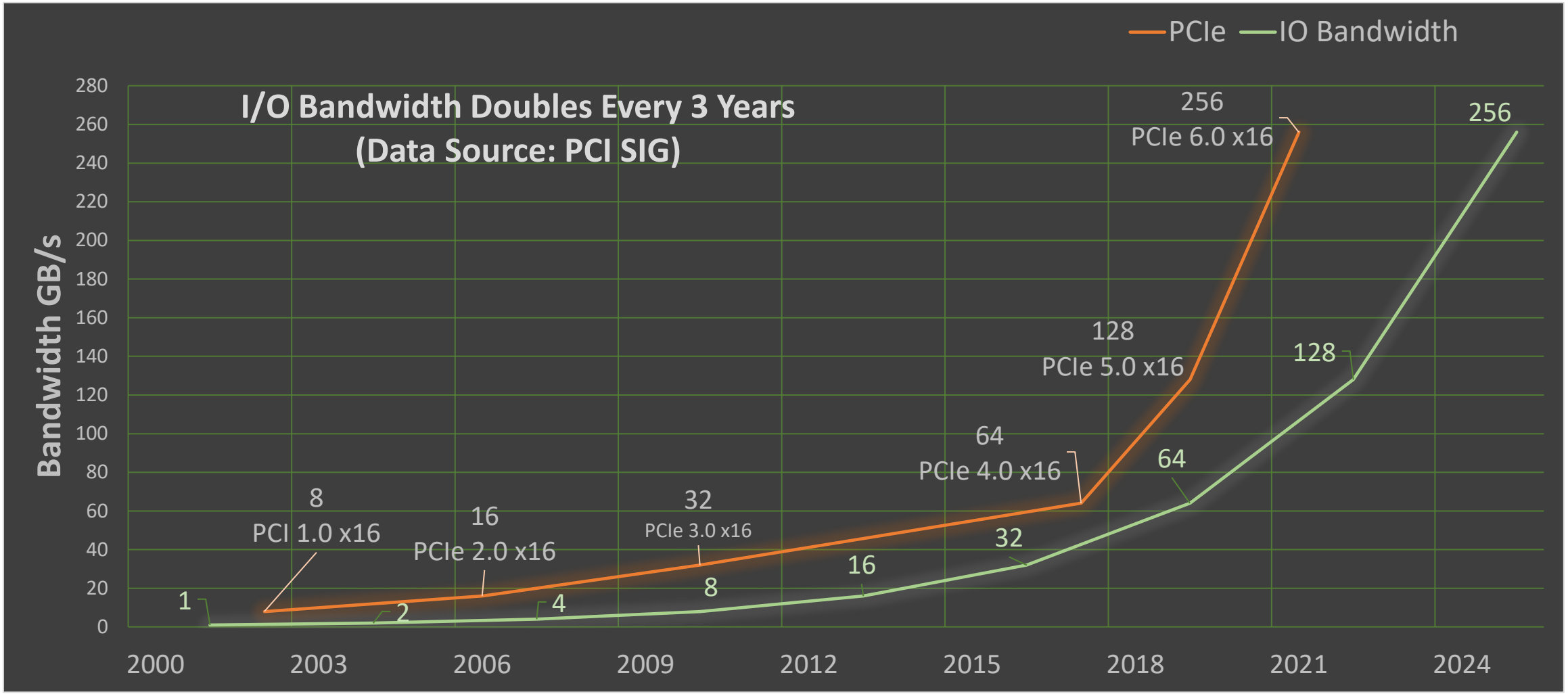
By Taufique Ahmed - 2018-12-19

At Electronica Munich 2018, Micron officially launched the Micron 2100AI/AT–an industrial- and automotive-grade PCIe NVMe Industrial SSD family based on 64-layer triple-level cell (TLC) 3D NAND technology. Available in 64GB-1TB BGA and 256GB-1TB M.2 form factors, the new 2100AI/AT series is Micron's first offering with a PCIe interface supporting the NVMe protocol that is designed to address the needs of the industrial segment: longevity, reliability, quality, ruggedness, and application-specific features such as namespace, autonomous power transitions, and boot emulation.

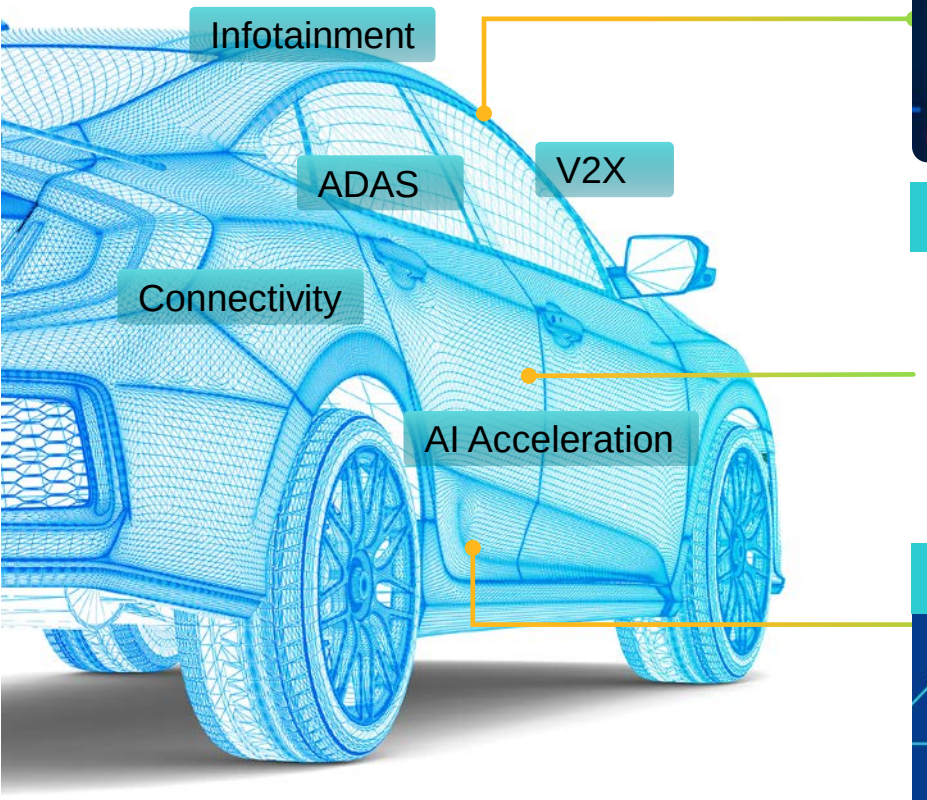
https://in.micron.com/about/blog/2018/december/the-role-of-pcie-nvme-industrial-ssds



Standard Has Headroom for I/O Bandwidth Needs



Automotive Applications Meet PCIe® Technology



INTELLIGENCE

Compute Performance

High bandwidth, scalable applications

SYSTEMS

System Performance

Latency, virtualization, scalability, security reach, functional safety, storage

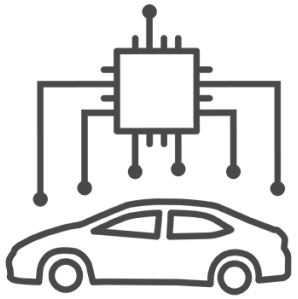
IC /SoCs

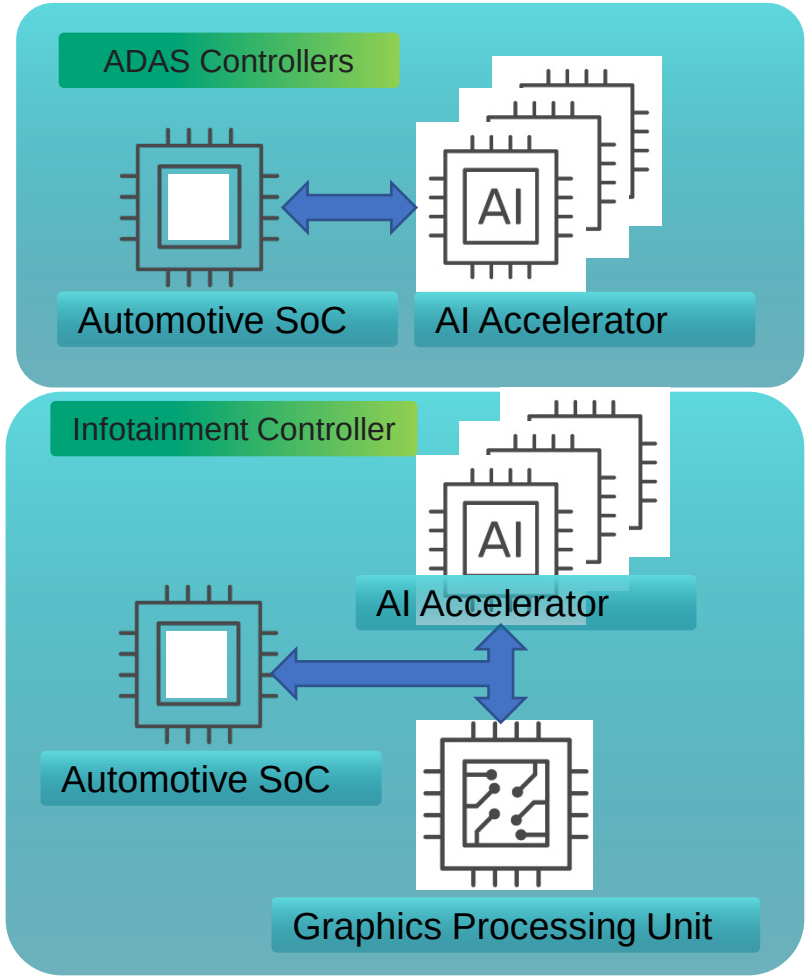
Silicon Performance

Power and thermal requirements

Silicon reliability in advanced process nodes

Compute Drivers

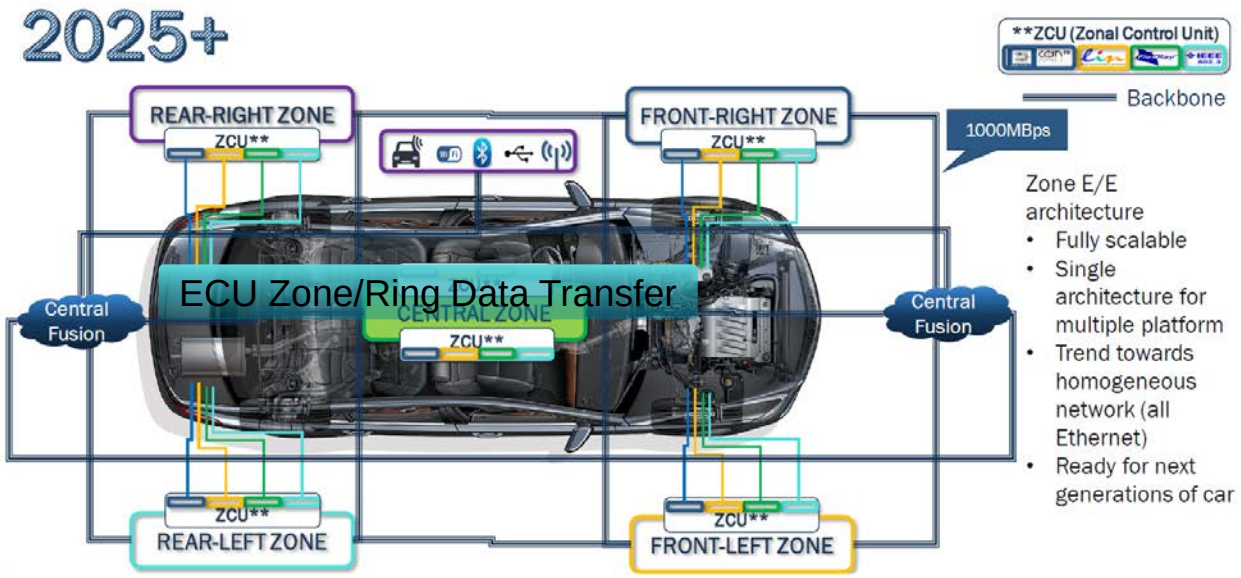




Requirement	PCIe Support
Bandwidth	Architecture version/Lane combination
Scalability	Configurable number of lanes
Low latency	Protocol timers and implementation dependencies
Virtualization	SR-IOV
Power management	ASPM, DPA, L1 substates, etc.
Security/trusted environments	IDE/DOE, ADISP
Functional Safety (FuSa)	Implementation specific

PCIe® Technology as the Data Backbone

ECU Processing Redundancy



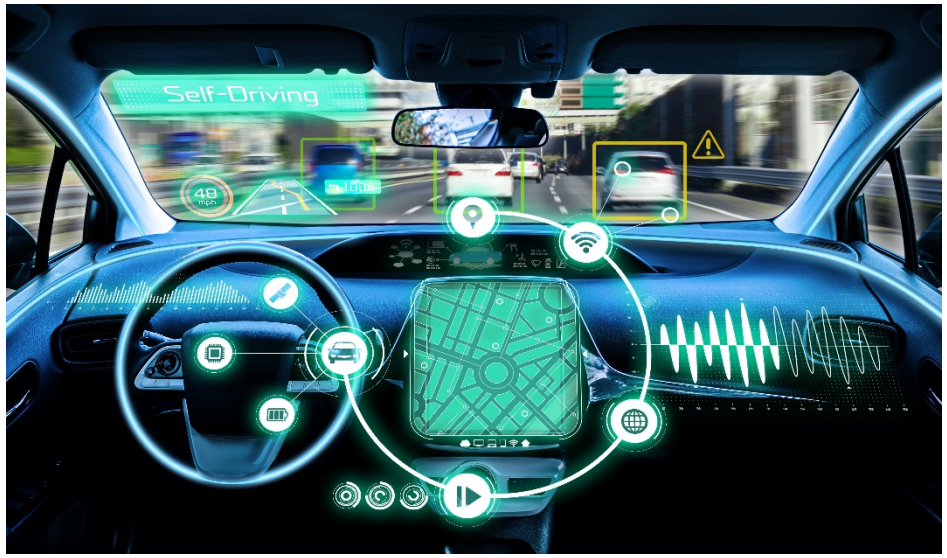
ECU Zone/Ring Data Transfer

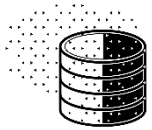
Sensor Fusion

Source: ON Semi webinar, 5/2021

Requirement	PCIe Support
Bandwidth (5-40Gbps)	Architecture version/Lane combination
Low latency	Protocol timers and implementation dependencies
Long reach	Standard and implementation (EMC/EMI, reliability)
Security/trusted environments	IDE/DOE, ADISP
Functional Safety (FuSa)	Implementation

Storage Evolves Towards PCIe® SSDs





Blackbox Recorder

Mapping Data

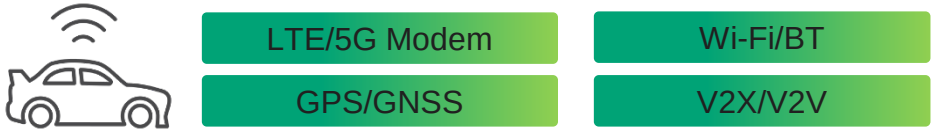
Cockpit Infotainment

Central Processing

Requirements		
High Endurance	Very Low Latency	Very High Density
Lifetime > 15 years	High bandwidth	Fast boot, fast startup
High temp data retention (Automotive Grade 1 and/or Grade 2)	Guaranteed minimum performance for writes	Virtualization capabilities

PCIe®/NVMe SSDs Are Widely Used as Storage Solutions	
PCIe RAS Features	Link CRC, ACK/NAK, Replay ACK/NAK timeouts End to End CRC
Power	L1 substates
Clocking	SRIS

Connectivity Applications with PCIe® Technology



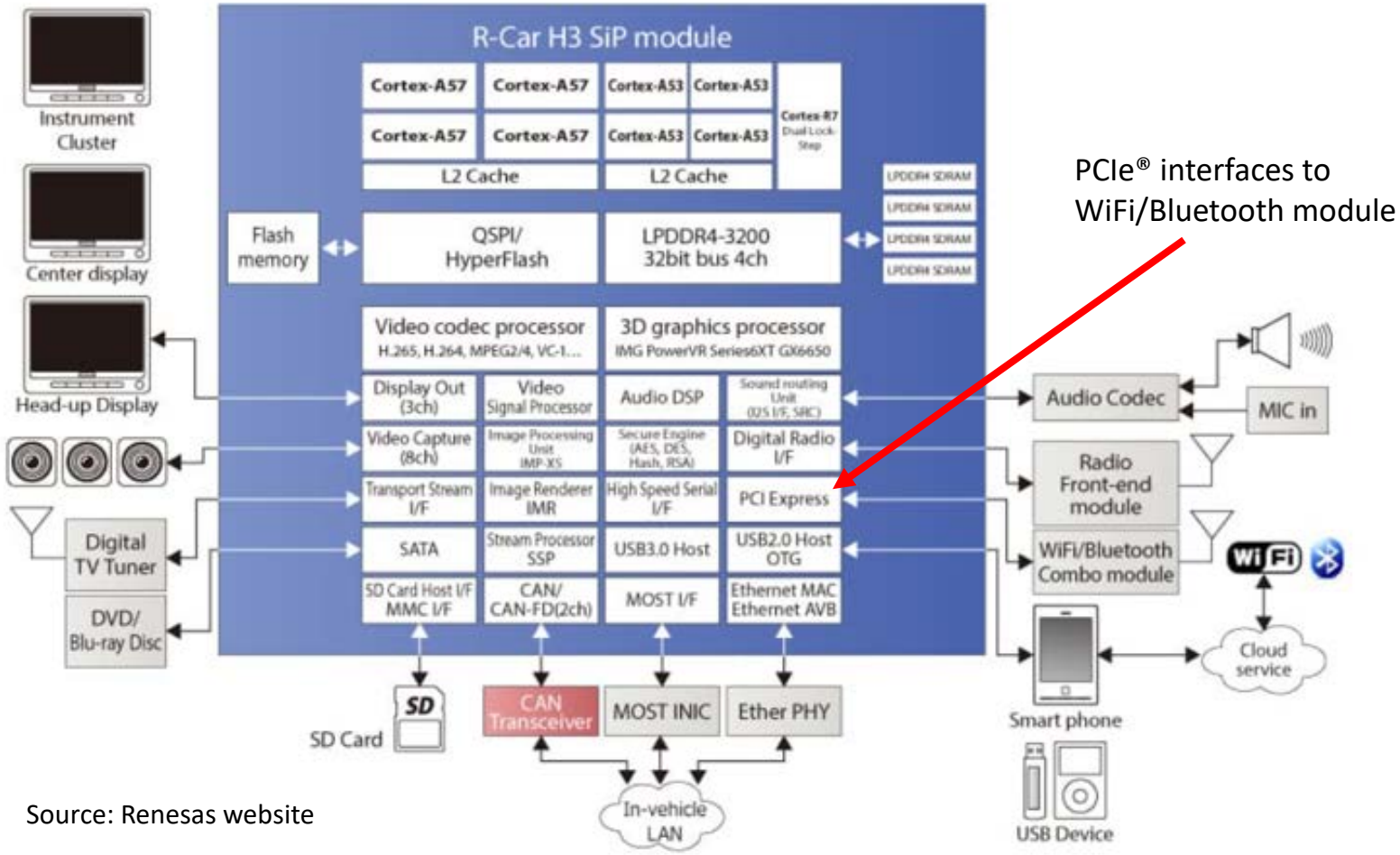
Requirement	PCIe Support
Scalable bandwidth	Architecture version/Lane combination
Low latency	Protocol timers and implementation dependencies
Long reach	Standard and implementation (EMC/EMI, reliability)
Security/trusted environments	IDE/DOE, ADISP
Functional Safety (FuSa)	Implementation dependent

Stringent Automotive Requirements

- Standardization
  - Well-defined roadmap for protocol
  - Commercial (long-term) availability from diverse suppliers
  - Interoperability
- Certification and qualification for harsher environments and functional safety
  - AEC- Q100/ISO 26262 processes
  - EMC/EMI requirements
  - Temperature and mechanical
- Safety and security
  - End to end measures
  - Regulatory compliance
- Lifetime
  - Aging requirements
  - Long-term availability, migration, upgrades
  - Backwards/forward compatibility

Commercial Automotive SoC Examples

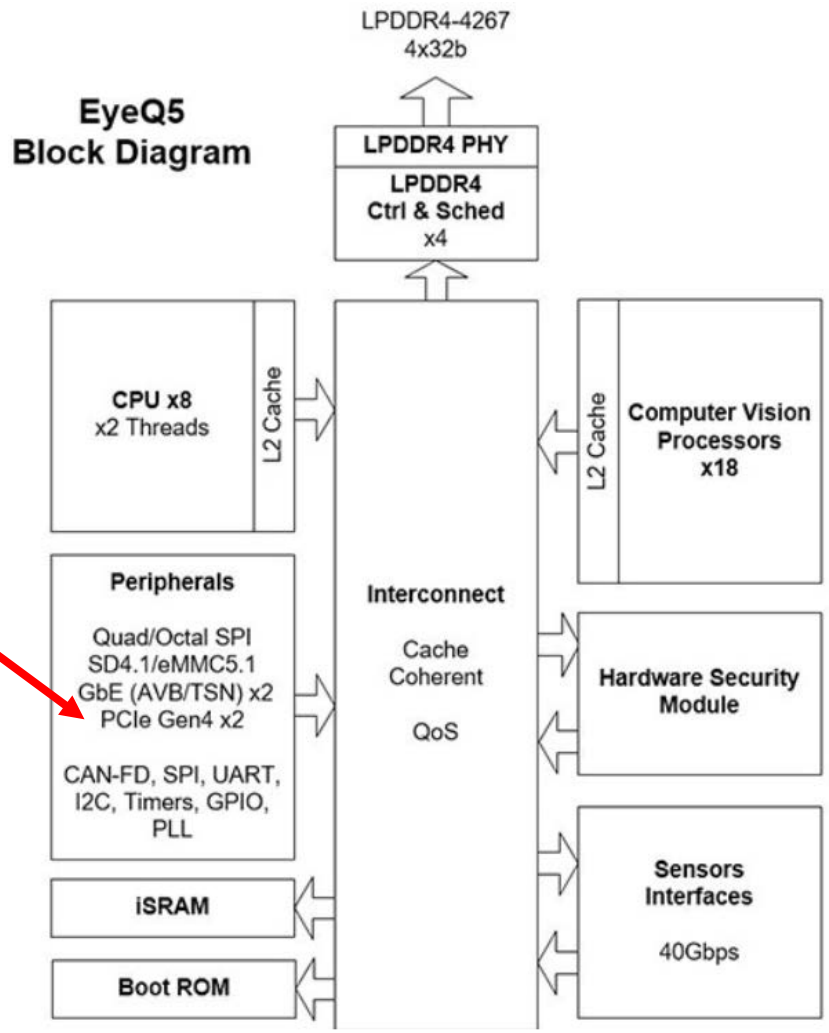
Infotainment SoC



Source: Renesas website

ADAS SoC

Two 16G PCIe® 4.0 interfaces built-in



Source: Mobileye website

PCIe® Architecture Addresses Advanced Automotive SoC Needs

- Established standards body, vibrant ecosystem, strong technical leadership
- Protocol specification and implementation meet the segment needs
  - Bandwidth, scalability, latency, security, reach, reliability
- Compliance and certification
- Broad silicon, software, and IP provider base and ecosystem
- Automotive Working Group established in PCI-SIG® to continue work on this exciting new frontier!

Thank you!

QUESTIONS?