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# Affordable and Safe high performance vehicle computers with ultra-fast on-board Ethernet for automated driving

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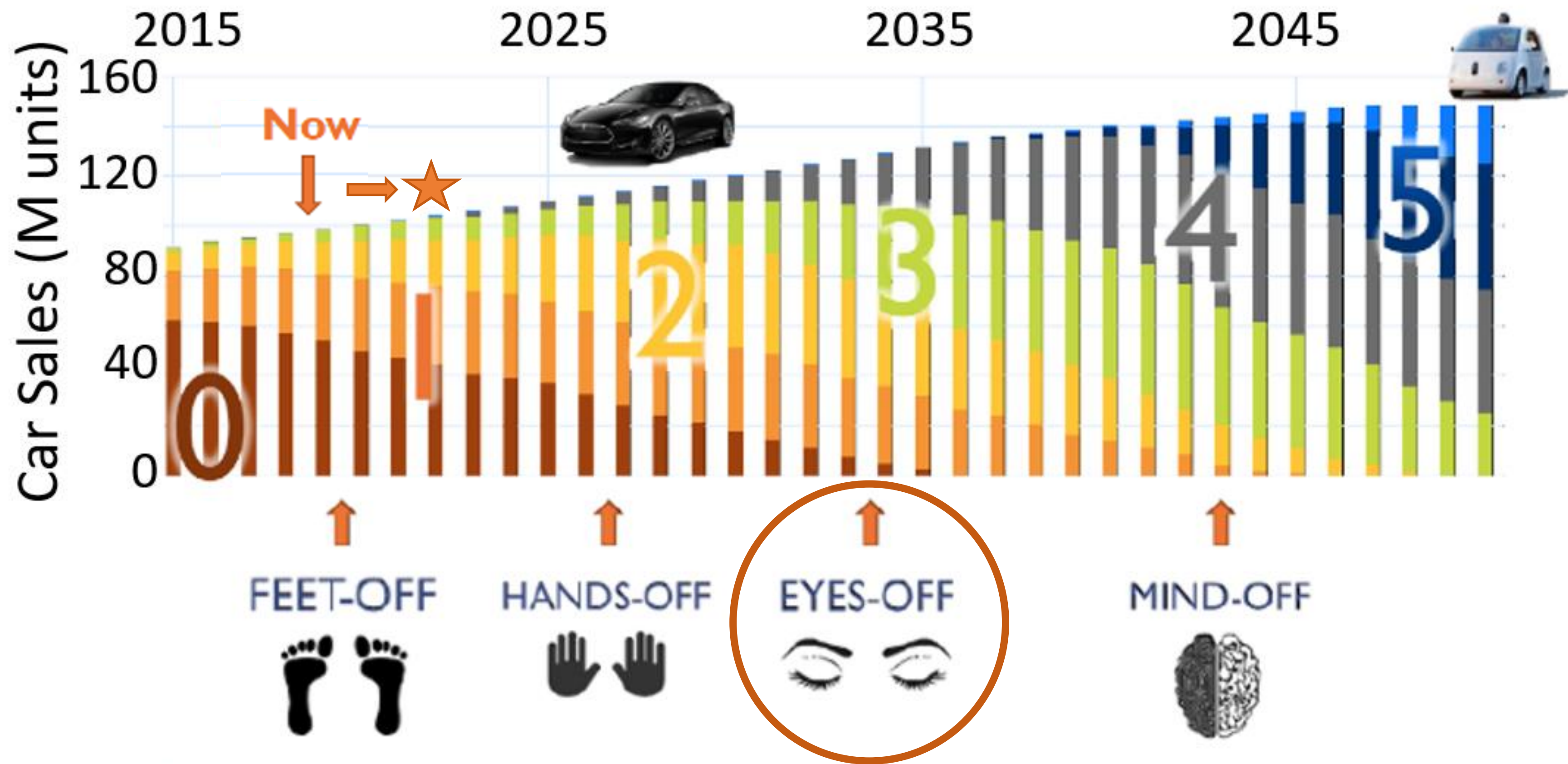
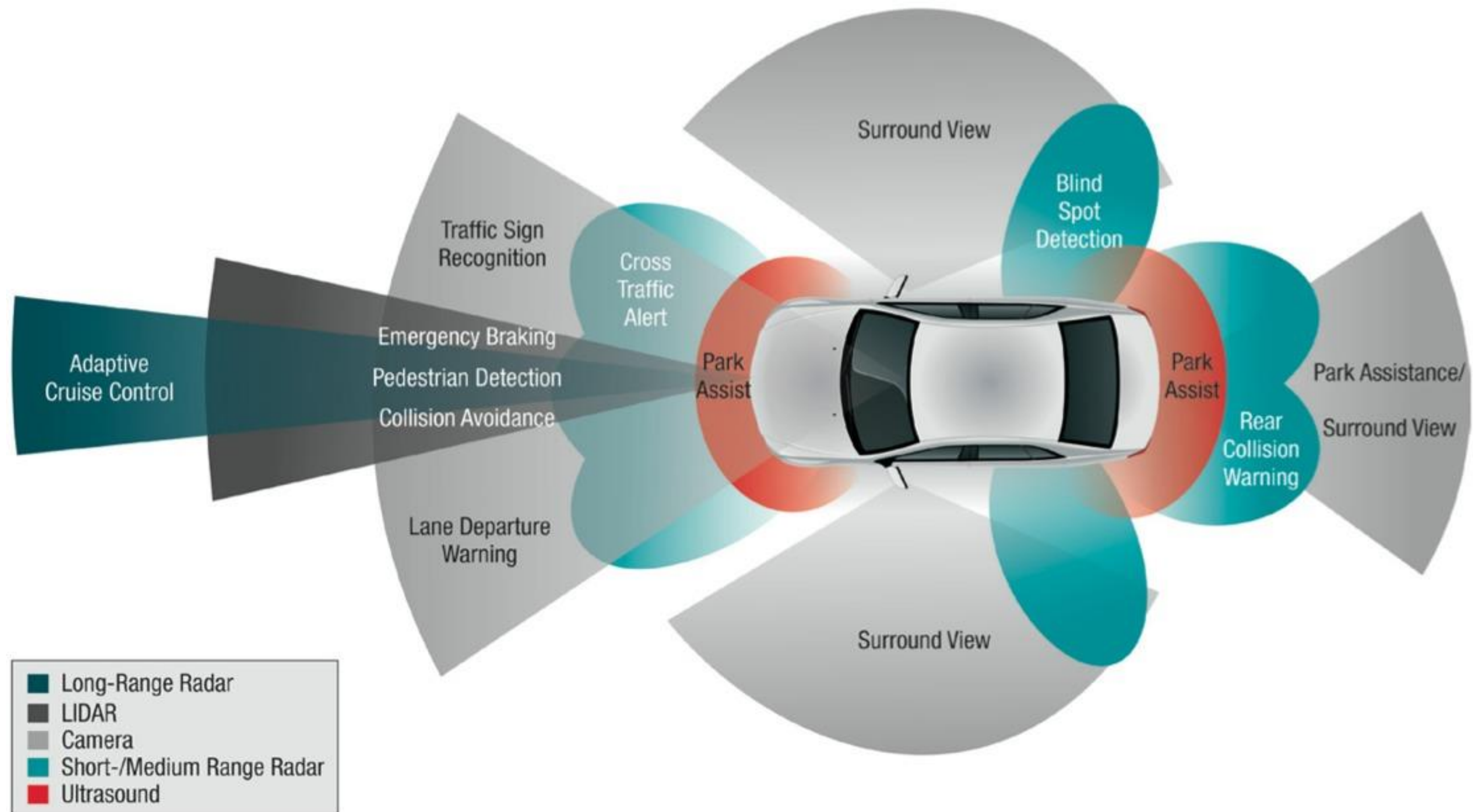
# Autonomous Driving



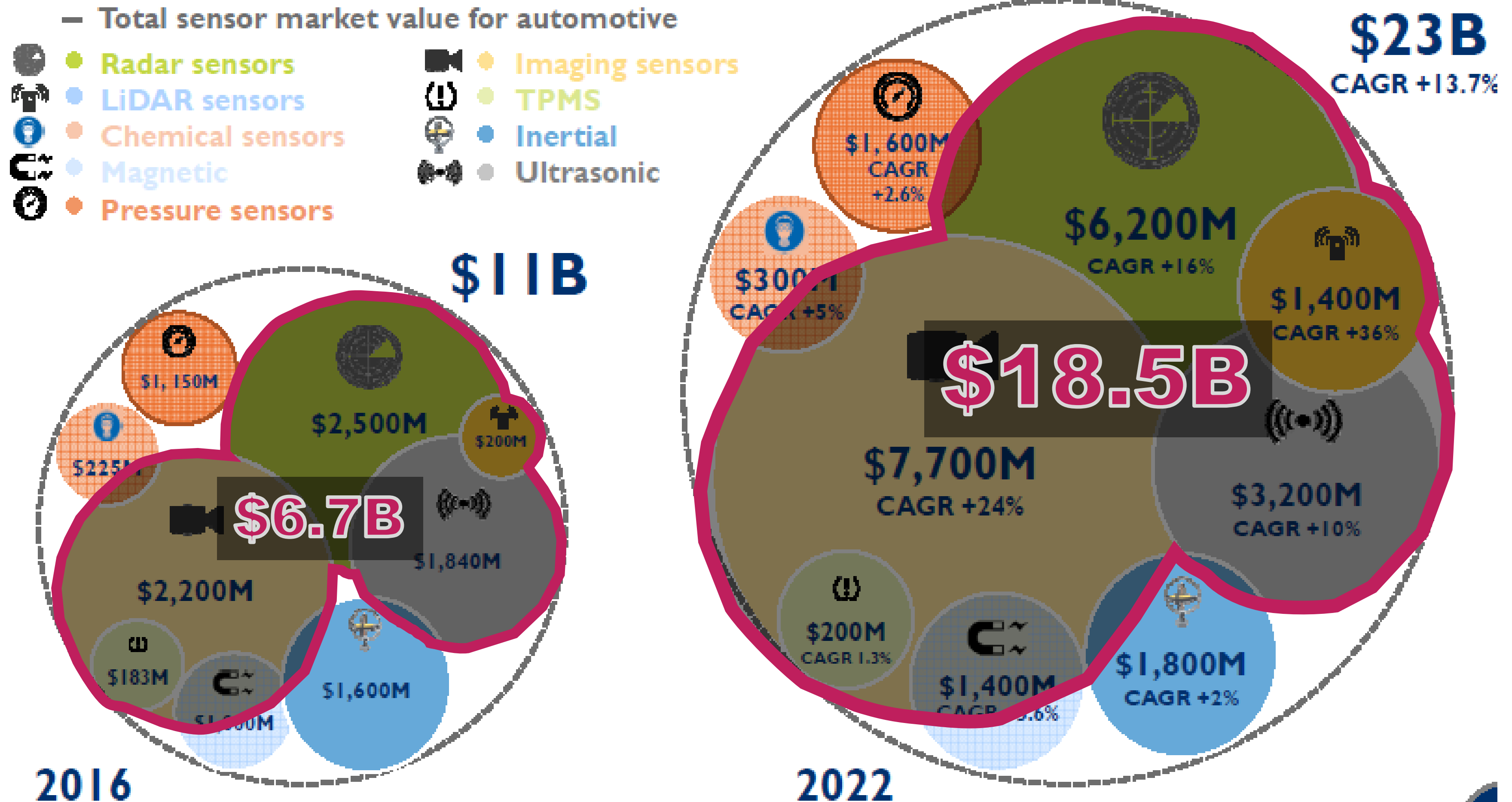

Ref: E.Celier et al., Yole: http://www.yole.fr/MEMS_Sensors_Automotive.aspx#.WvKglzYgrqw

# Autonomous Driving




Ref: W.T. Buller: Benchmarking Sensors for Vehicle Computer Vision Systems, Michigan Tech Research Institute, Ann Arbor/MI, USA, Dec. 2017; http://mtri.org/automotivebenchmark.html

# Autonomous Driving

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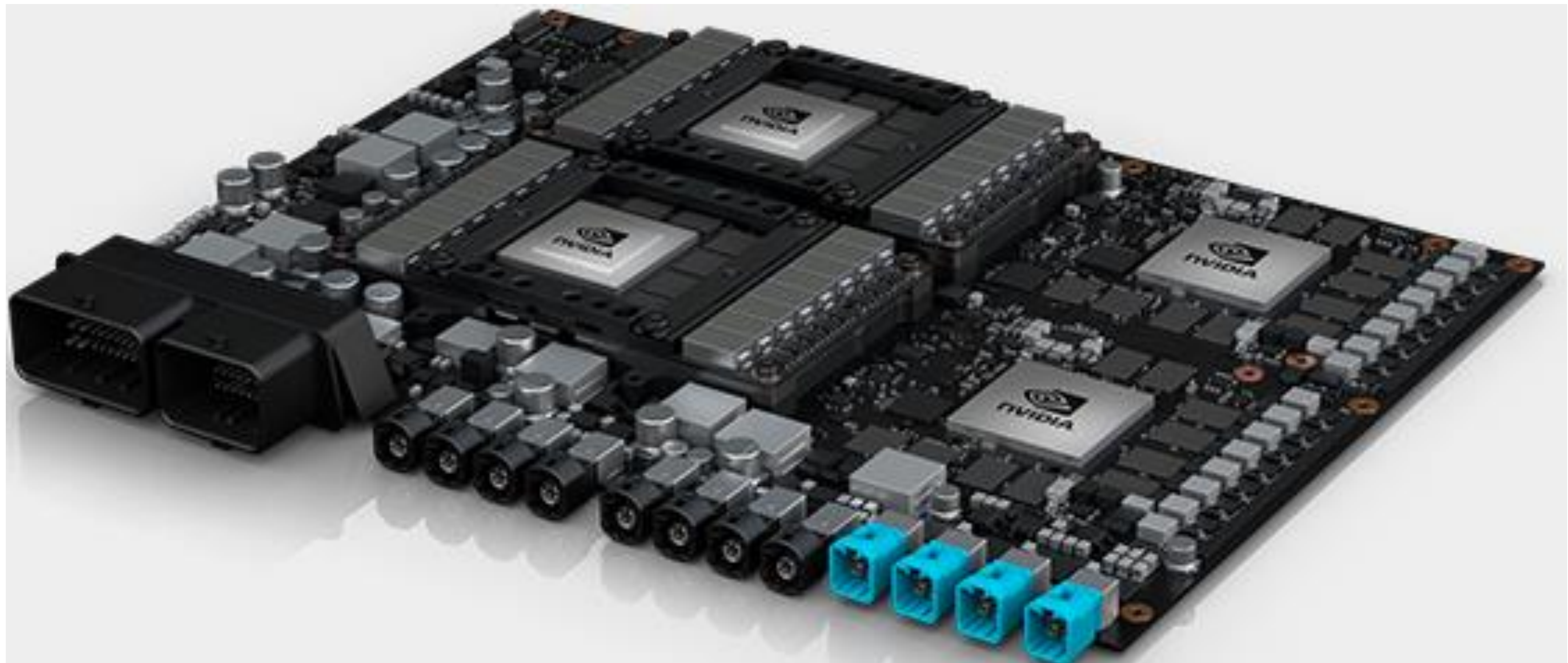
# High-Performance Vehicle Computers

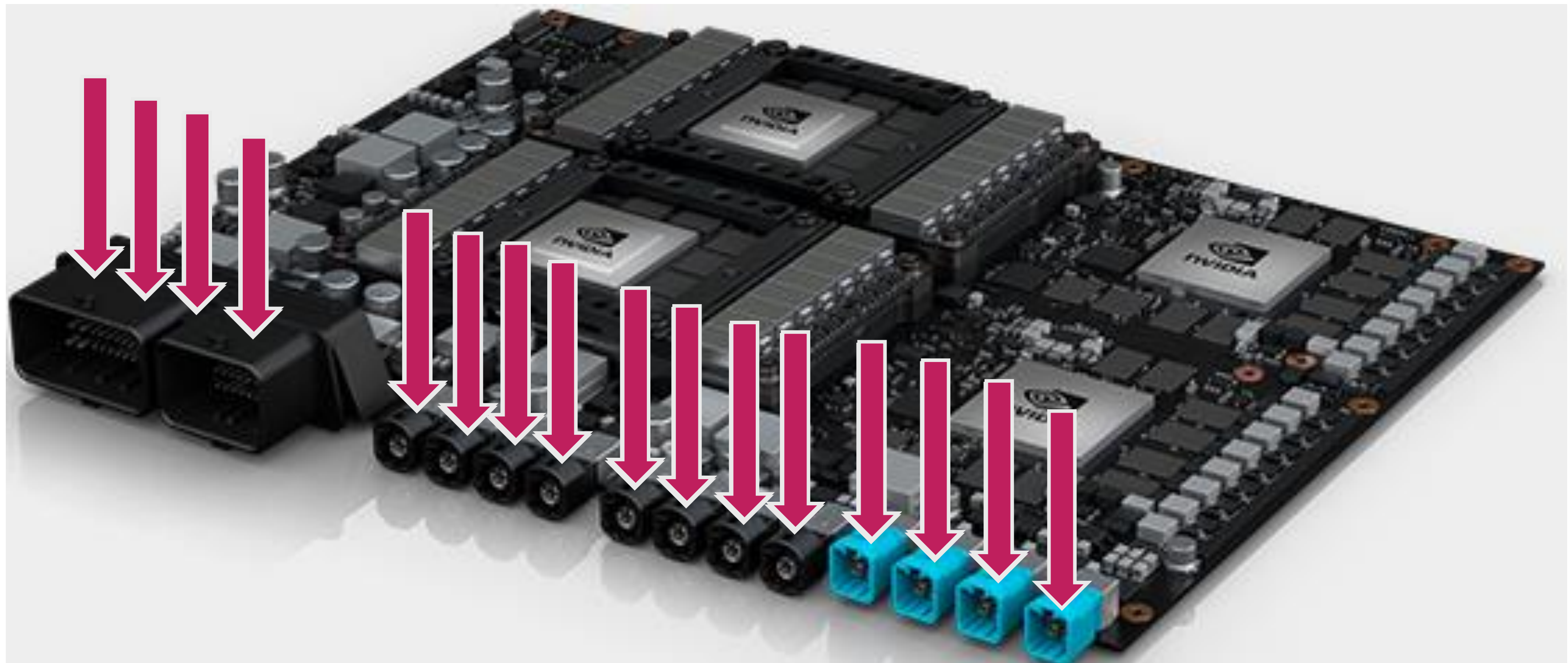
## Nvidia - Drive PX Pegasus: 300 TOPS



Ref: http://www.marketwired.com/press-release/nvidia-announces-worlds-first-AI-computer-to-make-robotaxis-a-reality-nasdaq-nvda-2236493.htm

# High-Performance Vehicle Computers

## Nvidia - Drive PX Pegasus: Communication Challenges



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# High-Performance Vehicle Computers

## Nvidia - Drive PX Pegasus: Thermal Challenges

Ref: http://www.marketwired.com/press-release/nvidia-announces-worlds-first-AI-computer-to-make-robotaxis-a-reality-nasdaq-nvda-2236493.htm

# High-Performance Vehicle Computers

## Nvidia - Drive PX Pegasus: Mechanical Challenges

GPU 1: 1000+ Pin BGA

CPU 1: 1000+ Pin BGA

GPU 2: 1000+ Pin BGA

CPU 2: 1000+ Pin BGA

Ref: http://www.marketwired.com/press-release/nvidia-announces-worlds-first-AI-computer-to-make-robotaxis-a-reality-nasdaq-nvda-2236493.htm

# High-Performance Vehicle Computers

## 1. Communication – Electrical Domain

10x higher data rate, multi-line connectors, security

## 2. Computation – Thermal Domain

GPU: 300 W dissipated heat … 900 W total system power

## 3. Integration – Thermo-Mechanical Domain

4x 1000+ balls, heavy heat removal gear, 6x service time

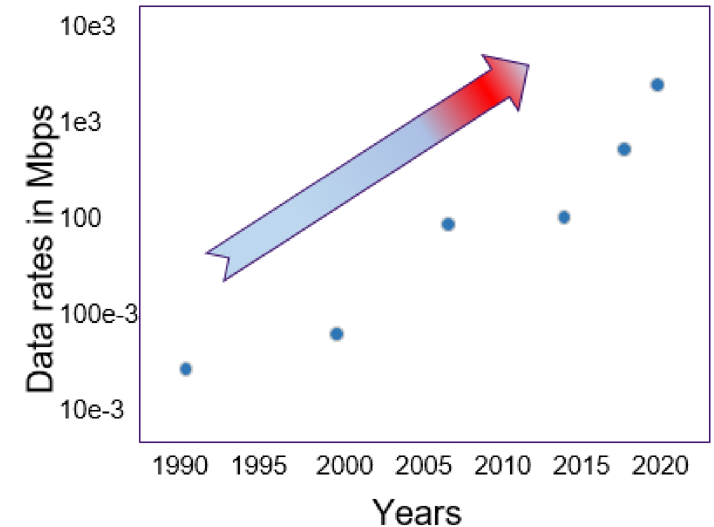
# HPVC – Electrical Domain

| | State of Today | L4/5 Requirements |
|---|---|---|
| Communication Protocols; Data Rate | LIN, CAN or CAN-FD; 10 Mb/s, 100 Mb/s | 100* BASE-T1 Ethernet; 1000 Mb/s, 10 Gb/s, … |
| A/D Converter Rate & Data Stream; Onboard Sensors | 20 MHz,16 bit → 1 Mb/s; 10x US, 2 Cameras | 80 MHz, 24bit → 2 Gb/s; 3-9 Radar, Lidar, 10 US, 4 Cameras (+1 IR) |
| Wiring Harness, Connector Technology | Unshielded Twisted Pair, (UTP), Unsealed & Sealed Technologies, Single Line Connectors | UTP, Shielded Twisted Pair (STP), Shielded Parallel Pair (SPP), Coaxial or Optical Cables (performance benchmark only); High-Speed Multi-Line Connectors |

**Approach:** Automotive Ethernet, Multi-Channel Connectors, Ethernet ICs

# HPVC – Electrical Domain

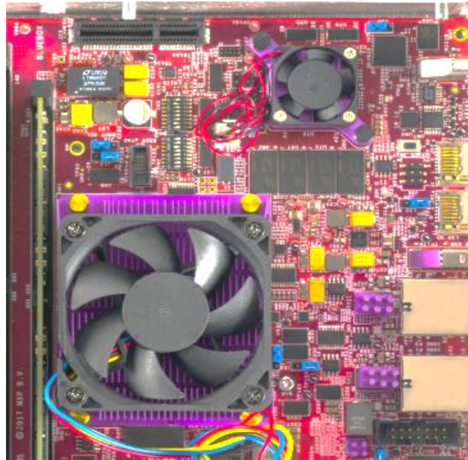
- AD cars: 20 radar, lidar, ultrasound, and video sensors for a comprehensive 360-degree real-time perception of its surrounding environment
- High Speed Bus System are required
  - e.g. High Ethernet data rate: 10 Gb/s and more
- New requirements to board network (including connectors & cables)
- Development of new highly integrated and scalable connector interface systems that supports the transfer of several high speed data rate
  - Space & cost advantage
  - Minimization number of connectors



Example of Control unit with
Multi-Channel High-Speed Ethernet capability

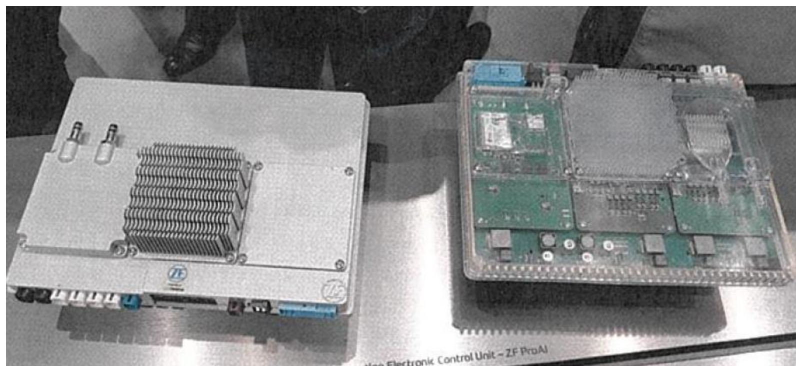
# HPVC – Thermal Domain

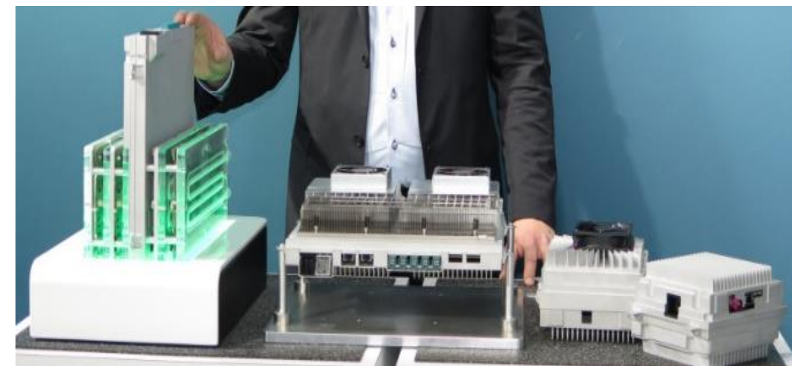
State of the Art


NXP BlueBox (30 W)

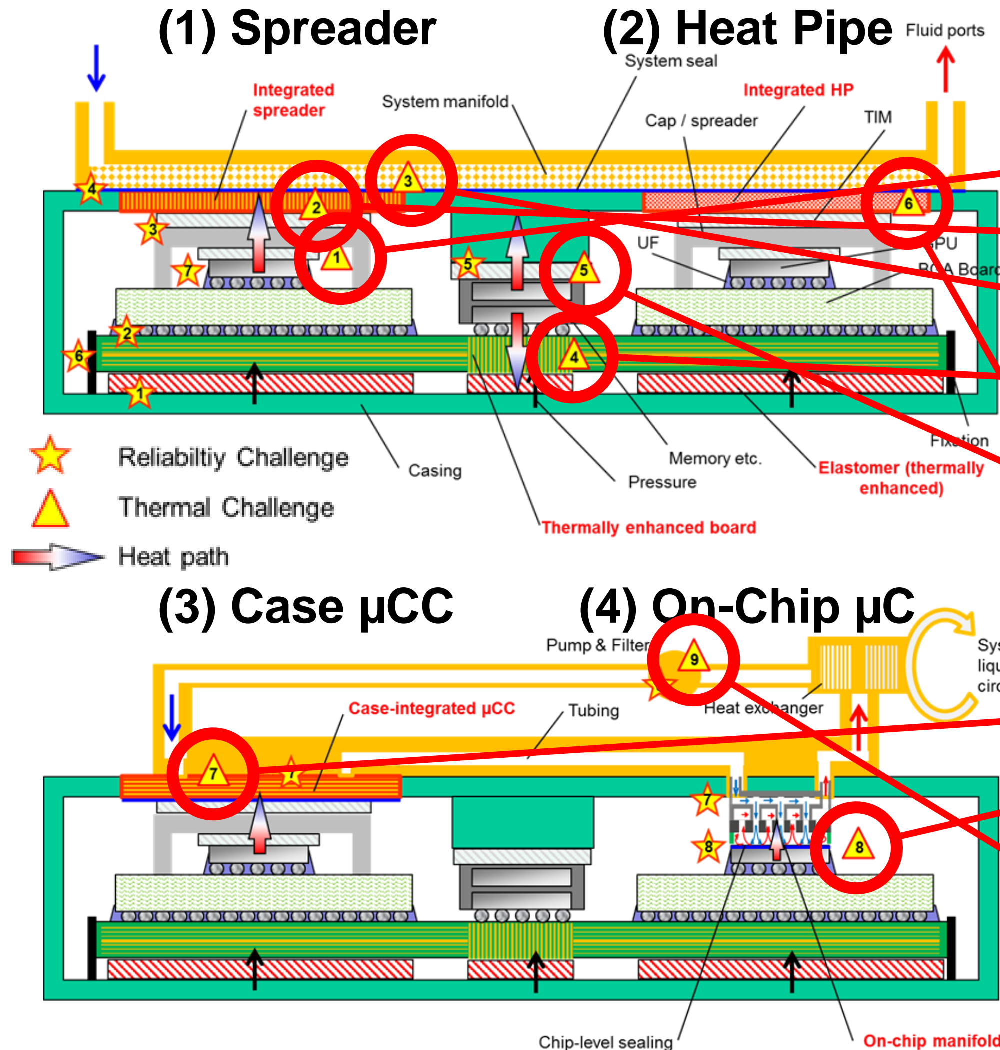
Tesla (dash board)

Audi (behind rear seats)


ZF ProAI (Nvidia Xavier, 30 TOPS)


Visteon modular system

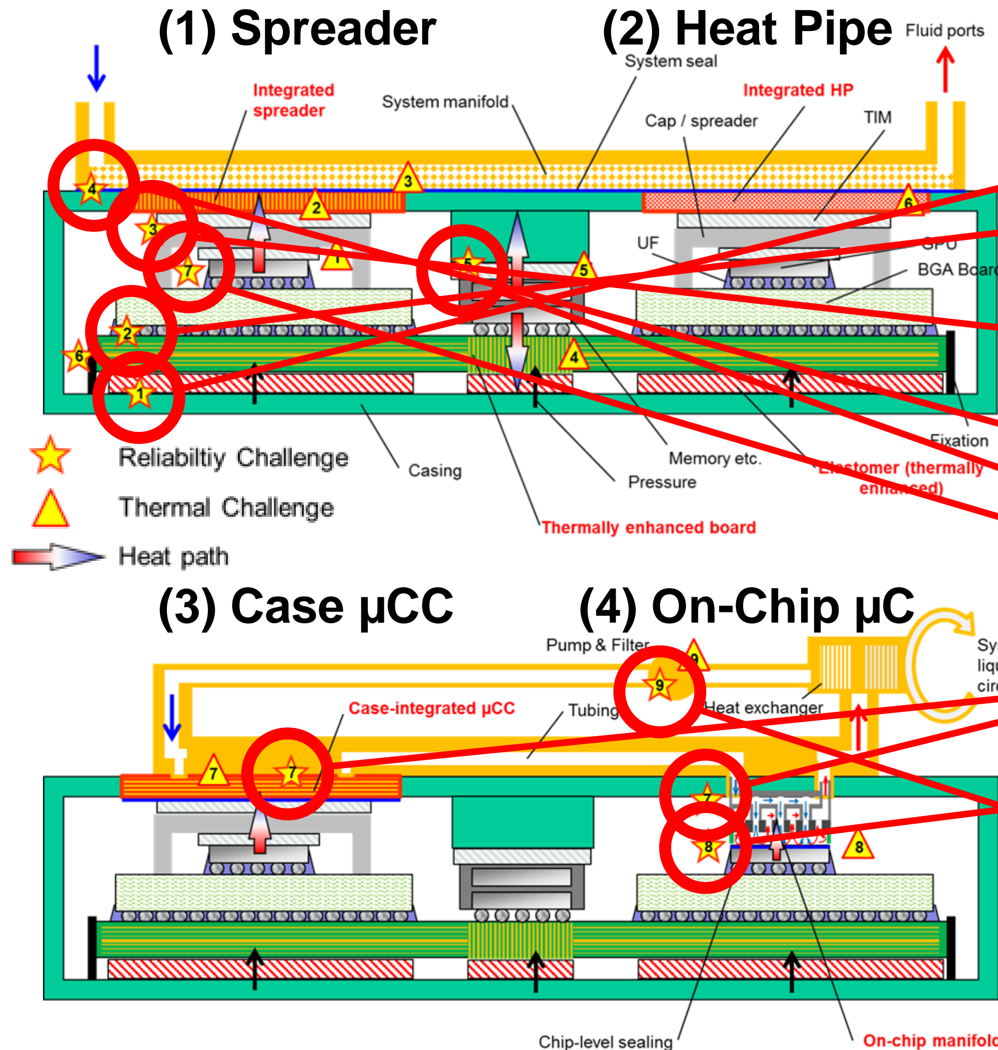
# HPVC – Thermal Domain




## Thermal Challenges

1. TIM (first bottleneck),
2. Interface to spreader,
3. Heat transfer into manifold,
4. Thermal enhancement of substrate,
5. Heat path encapsulated packages,
6. Heat pipe performance,
7. µ-channel cooler performance,
8. Jet impingement cooler performance,
9. Secondary liquid loop with heat exchanger and pump

# HPVC – Thermal Domain




## Thermo-mechanical Challenges

1. System tolerance, CPI,
2. UF delamination, solder joint reliability,
3. Interface toughness / low stress bond,
4. System sealing,
5. Component sealing,
6. Fixation mechanical decoupling,
7. Leak proof µC cooler & tubing connections,
8. Leak proof jet impingement,
9. Reliable & corrosion-free secondary cooling circuit.

# HPVC – Thermo-Mechanical Domain

## Wafer-Fab

### Back-end of Line

Electro migration,
Stress migration,

Dielectric Break-down

## Electronic Packaging & System Integration

### Component

Moisture Level 1-3,
Thermal Cycles,

Mechanical Loads, …

### Module / Board

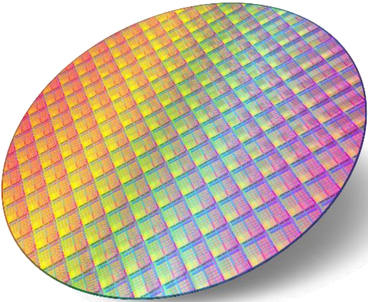
Moisture Level 1-3,
Thermal Cycles,

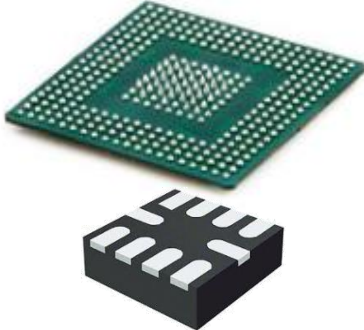
Mechanical Loads, …

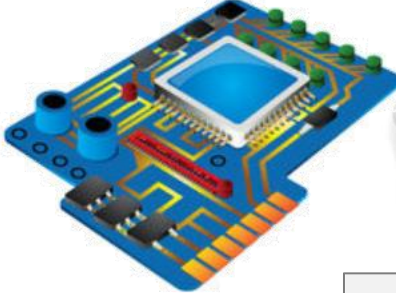
### System / Application

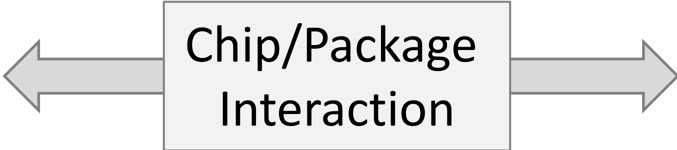
Thermal Cycles,

Mechanical Loads, …










1st Level
Reliability

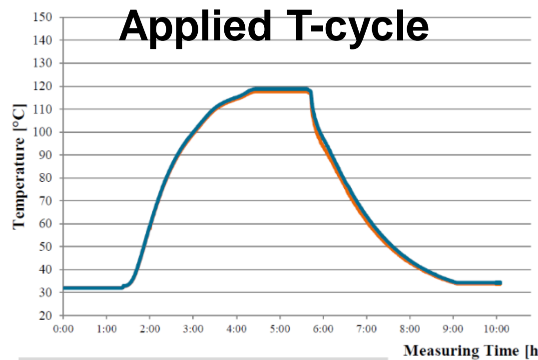
2nd Level
Reliability

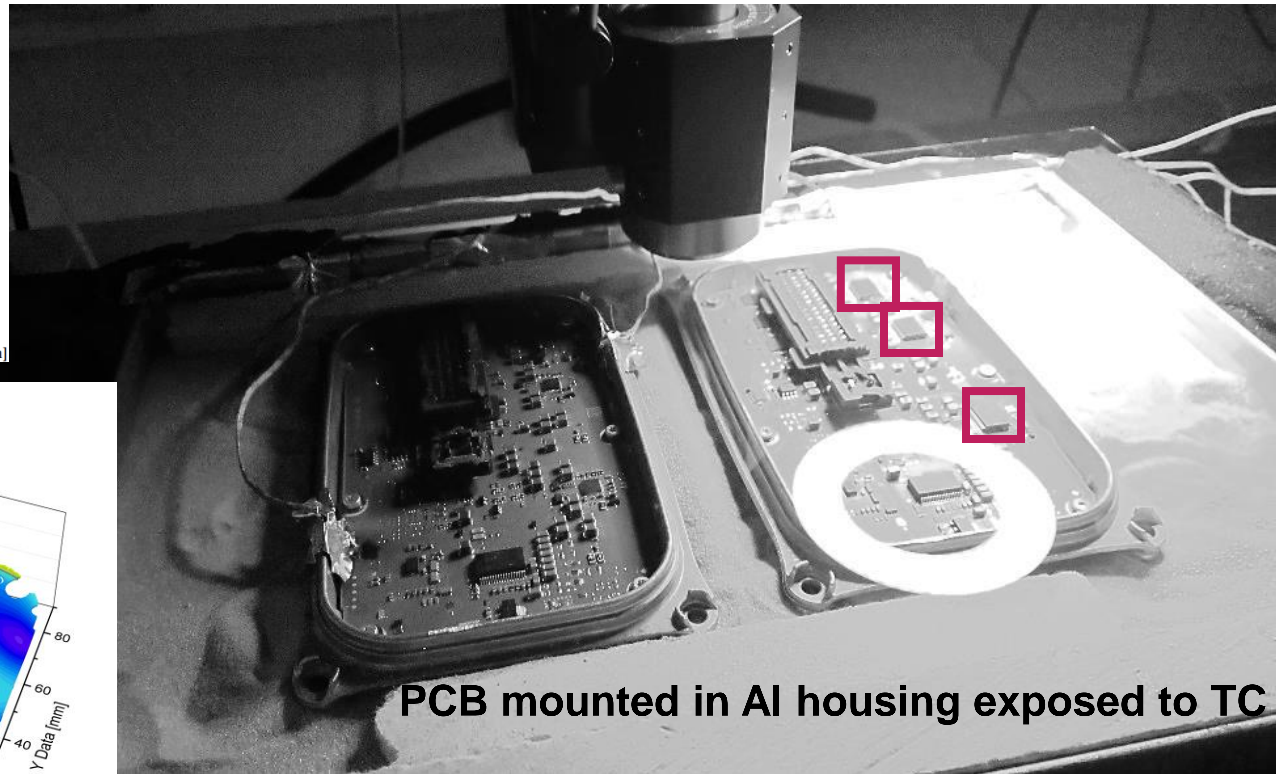
*3rd Level
Reliability?*

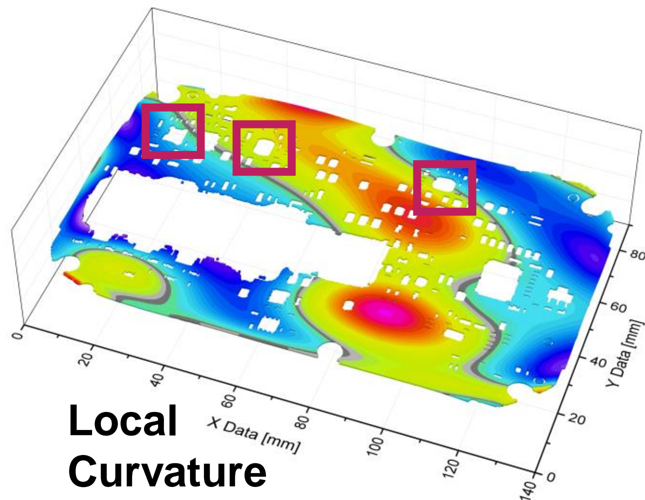
Many thermo-mechanical analyses & standard tests are limited in complexity by not considering application level.

# HPVC – Thermo-Mechanical Domain

Assessment of board warpage and in-plane effects due to thermal cycling at mounted state on application level




Local Curvature

AE Demonstrator (ECU)

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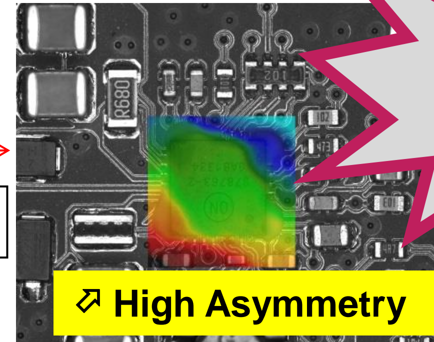
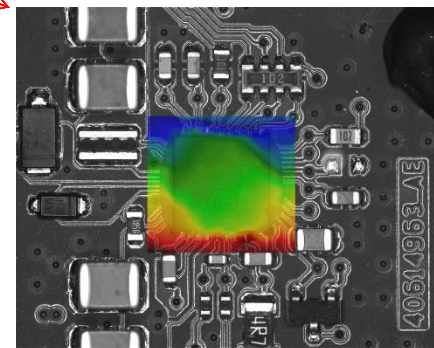
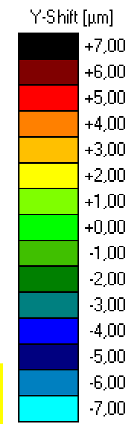
# HPVC – Thermo-Mechanical Domain

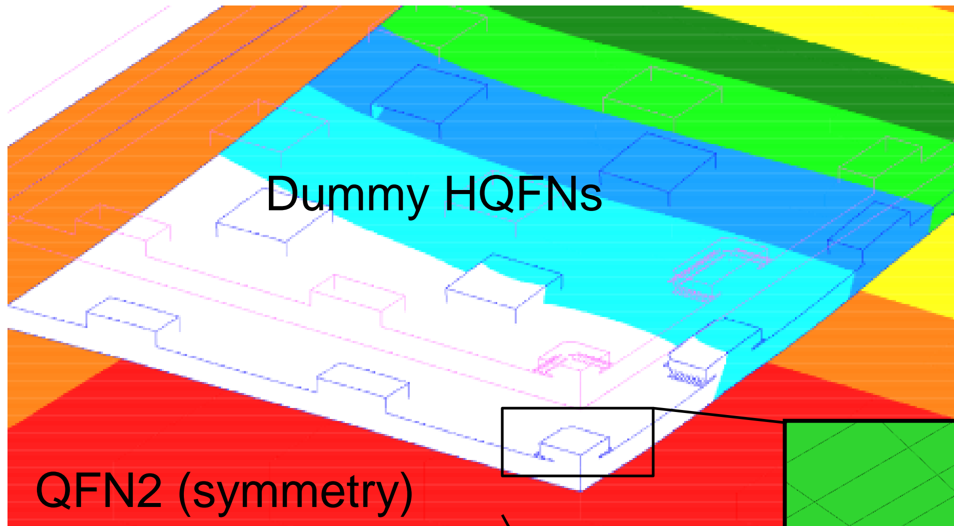






# HPVC – Thermo-Mechanical Domain

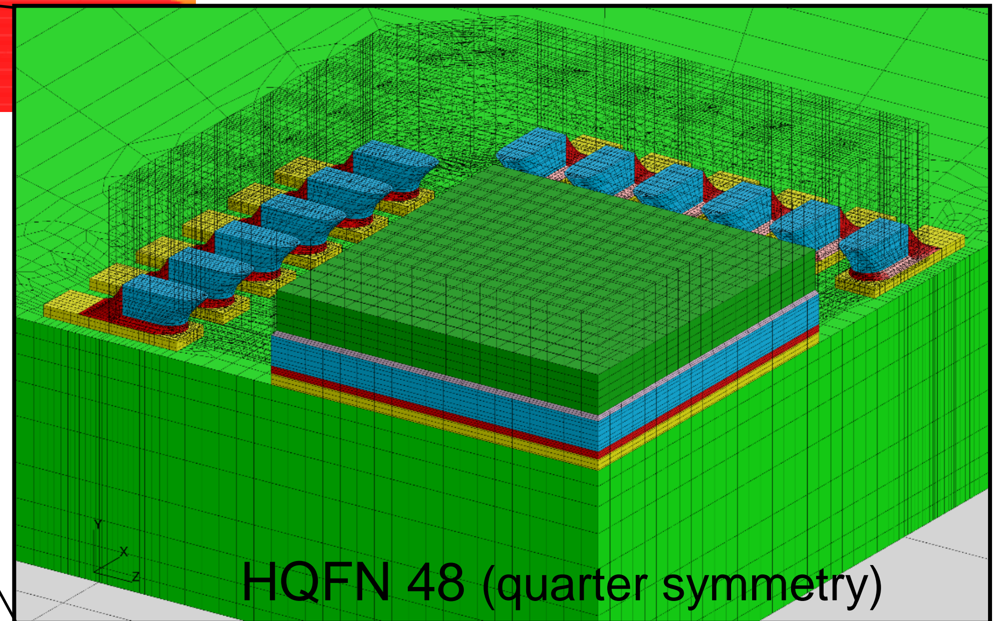



## Finite Element Analysis

### Thermal cycle 125 / -40°C, 1h

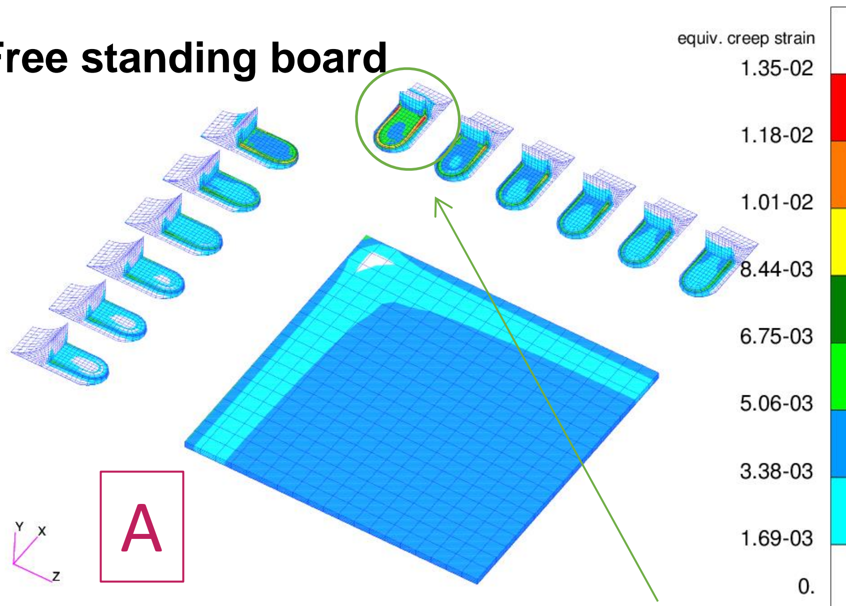
Stress analysis considering three thermo-mechanical loading conditions:

- Free standing board; no super-imposed loading (= usual assump-tion in board level assessments).
- In-plane stretching with an effective CTE of 20 ppm/K due to mounting on the Al case
- In-plane stretching with an effective CTE of 20 ppm/K and additional cyclic warpage with a bending radius of 2.8 m or 4.8 m.



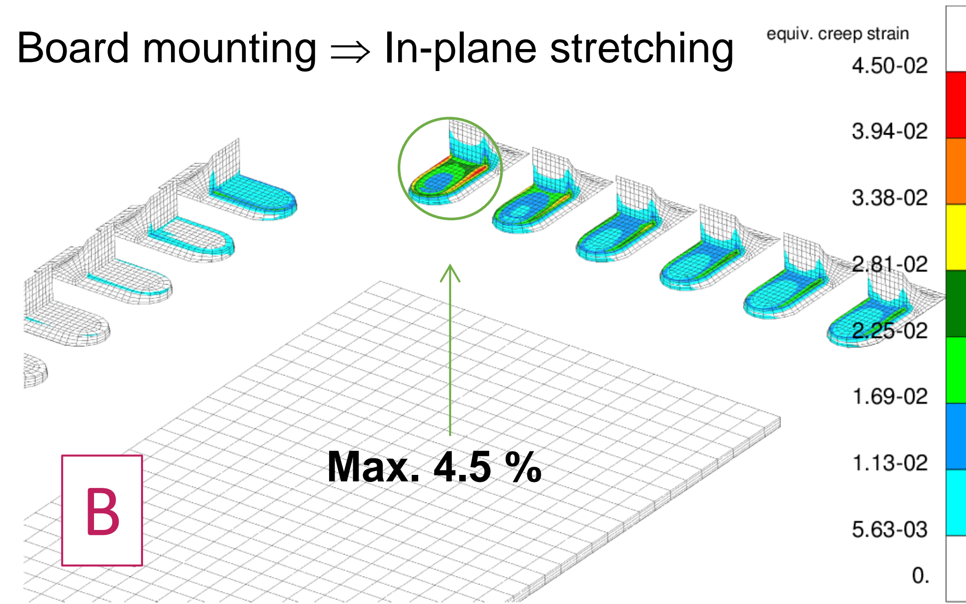
# HPVC – Thermo-Mechanical Domain

**Free standing board**

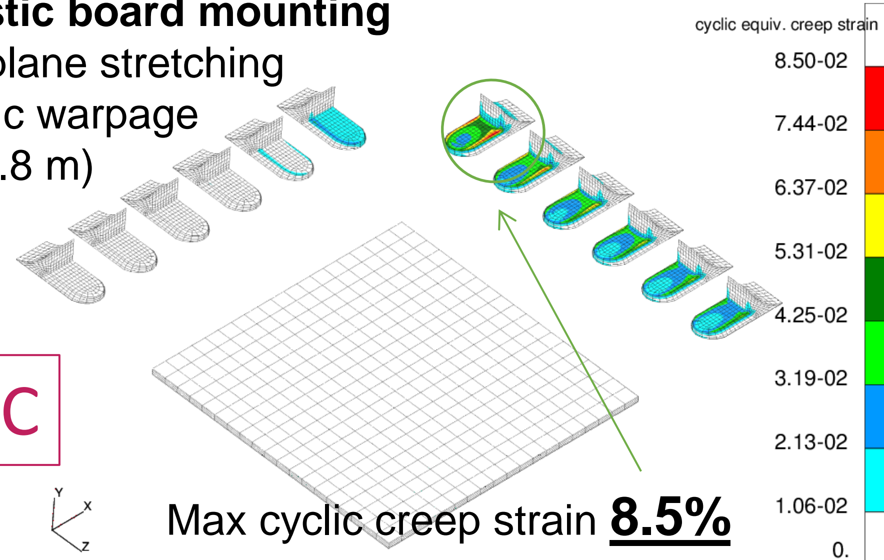



Max cyclic creep strain **1.35%**

Board mounting ⇒ In-plane stretching




**Realistic board mounting**
⇒ In-plane stretching
& cyclic warpage
(R = 2.8 m)




Max cyclic creep strain **8.5%**

- Highest creep strain at corner joint
- Strain magnitude massively dependent on mounting situation

# HPVC – Thermo-Mechanical Domain

Normalized prediction for free standing PCB (2nd level reliability)

Normalized decline of TC lifetime as function of the system mounting situation (3rd level reliability)

Mean cycles to failure, normalized

1.2
1.0
0.8
0.6
0.4
0.2
0.0

A
B
C
-90%

free standing
mount w/o warp, screws only
mount w/o warp, fully fixed to Al
mount with warp, screwed, r=4.75 m
mount with warp, fixed, r=4.75 m
mount with warp, fixed, r=2.8 m

Al housing influences the thermo-mechanical reliability massively

**Upgrade of the reliability assessment schemes is necessary**

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# Summary and Conclusion
# High-Performance Vehicle Computers

**1. Communication – Electrical Domain**

Data rate: 10 Gbit/s, Automotive Ethernet, Ethernet ICs

**2. Computation – Thermal Domain**

Automotive heat pipes … Microchannel liquid coolers

**3. Integration – Thermo-Mechanical Domain**

Undermolding, potting, Combined testing, Digital twinning

# Acknowledgments

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**Thank you for your attention!**

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