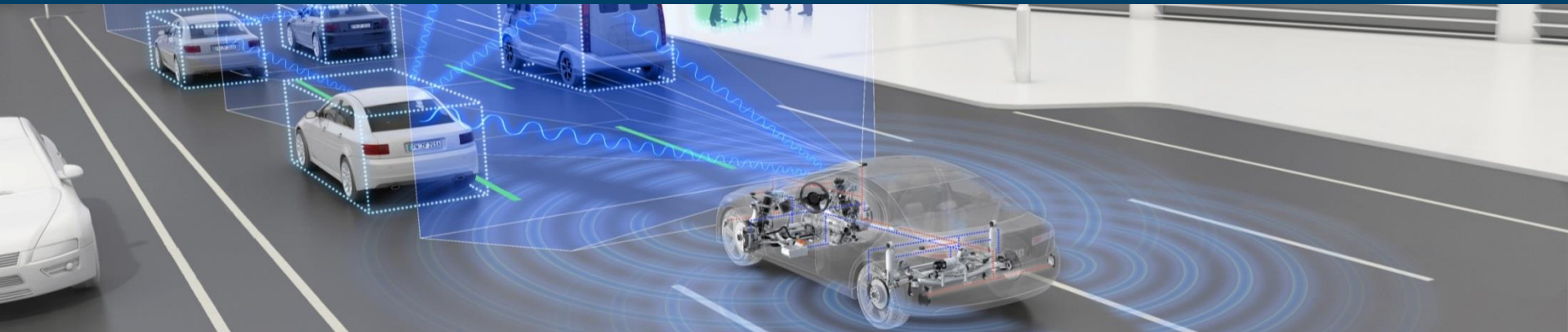




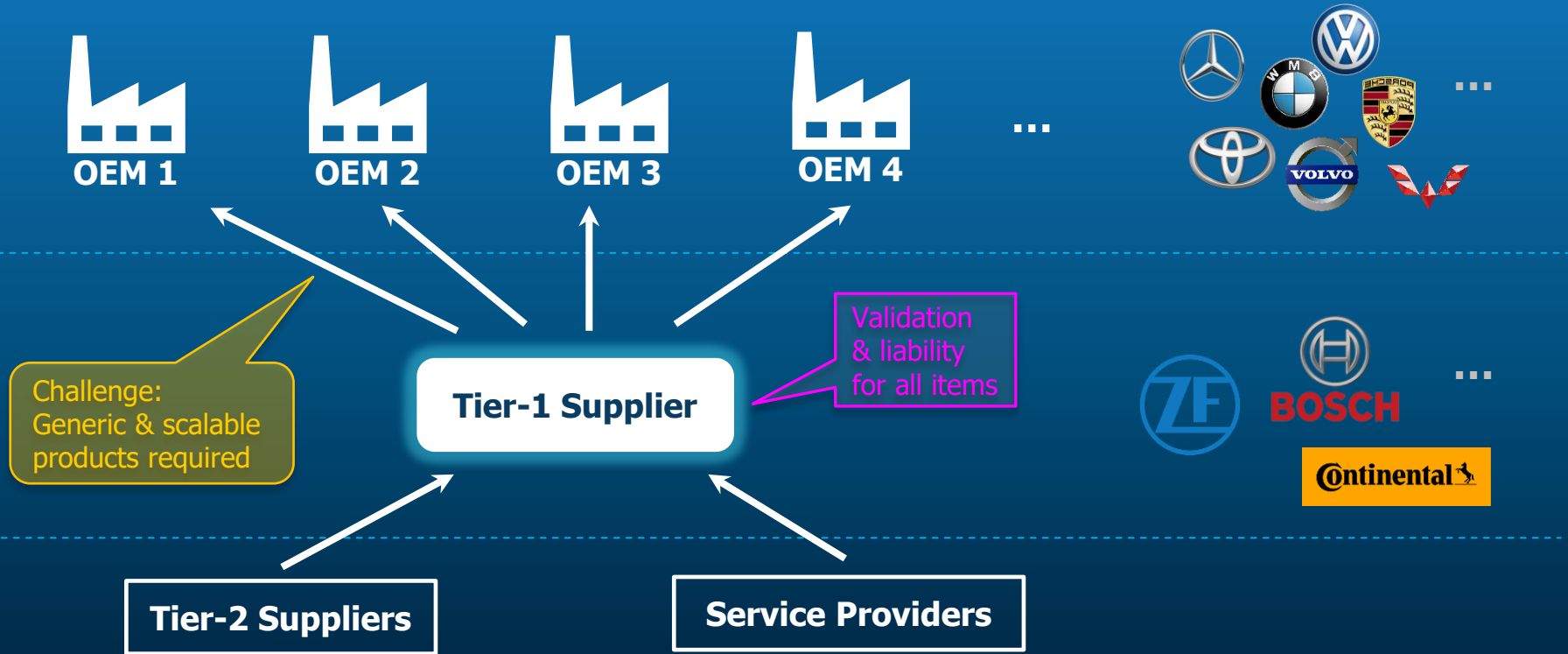
# Automated Driving

Physicists in Automotive Industries

Oliver Maria Kind | ZF Group | BCGS Workshop | April 19th, 2024



# Introduction - Automotive Industry Landscape



\*) OEM = original equipment manufacturer

# ZF – The Gearbox Factory (founded 1915 by Zeppelin et al)



Where it all began – Friedrichshafen 1900: Zeppelin airship LZ1

# Financial Overview 2023



**EUR 46.6 billion**  
sales



**168,738**  
employees



**EUR 3.5 billion**  
Research &  
Development



**EUR 2.0 billion**  
adjusted EBIT



**5.1%**  
adjusted  
EBIT margin



**EUR 2.2 billion**  
investments in  
property, plant,  
and equipment

# Key Figures – Locations

## North America

Locations: 35  
Employees: 35,307

## Europe

Locations: 82  
Employees: 93,706

## Asia-Pacific

Locations: 38  
Employees: 29,454

168

production locations  
in 32 countries

19

main development locations  
in 9 countries

Global service network with more  
than 15,000 workshop partners

## South America

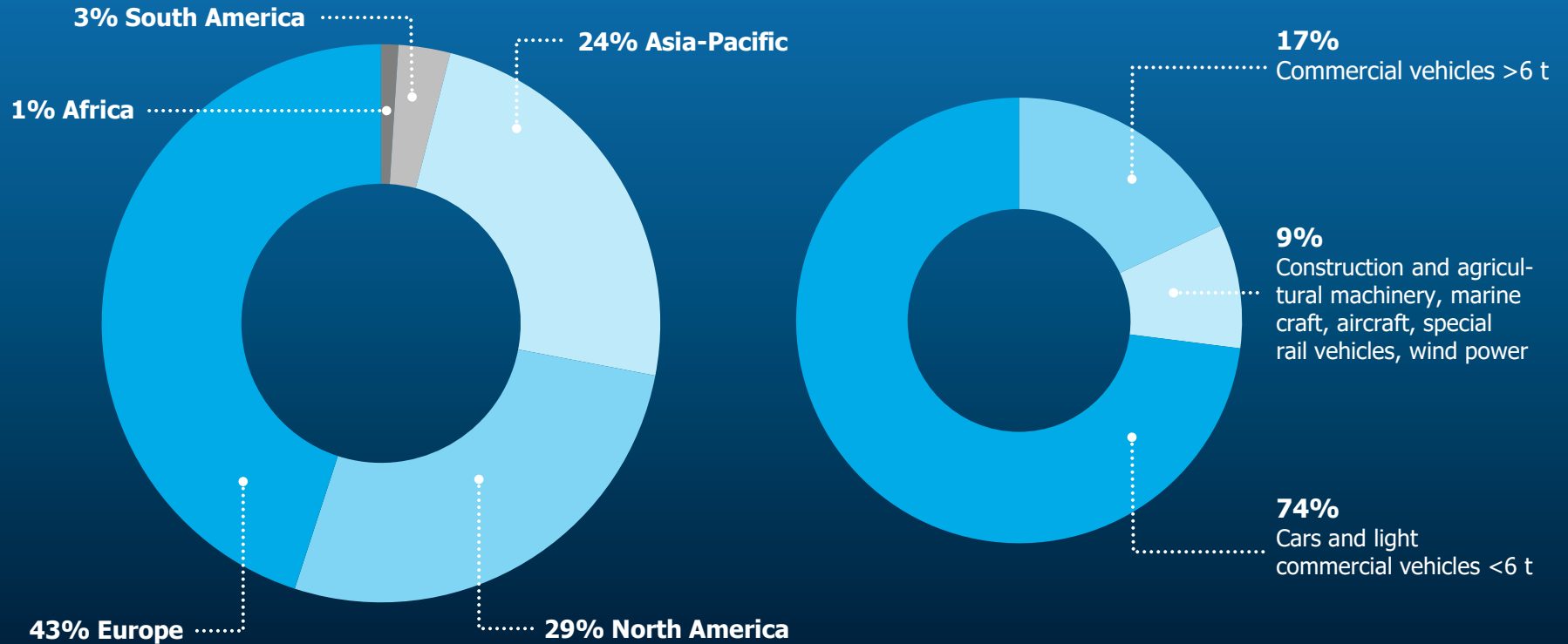
Locations: 9  
Employees: 5,592

## Africa

Locations: 4  
Employees: 810

Worldwide Presence – Production, Development, Sales and Service

# Overall Sales €43.8 Billion in 2022



# ZF shapes Next Generation Mobility in 4 Technology Domains



Automated Driving



Vehicle Motion Control



Integrated Safety



Electric Mobility

# Division U provides products for a majority of ZF's safety systems

Occupant Safety Systems

Advanced Driver Assistance Systems

Electric Drives

Chassis Components

Steering Systems

Damping Systems

Safety Electronics

Active Chassis Systems

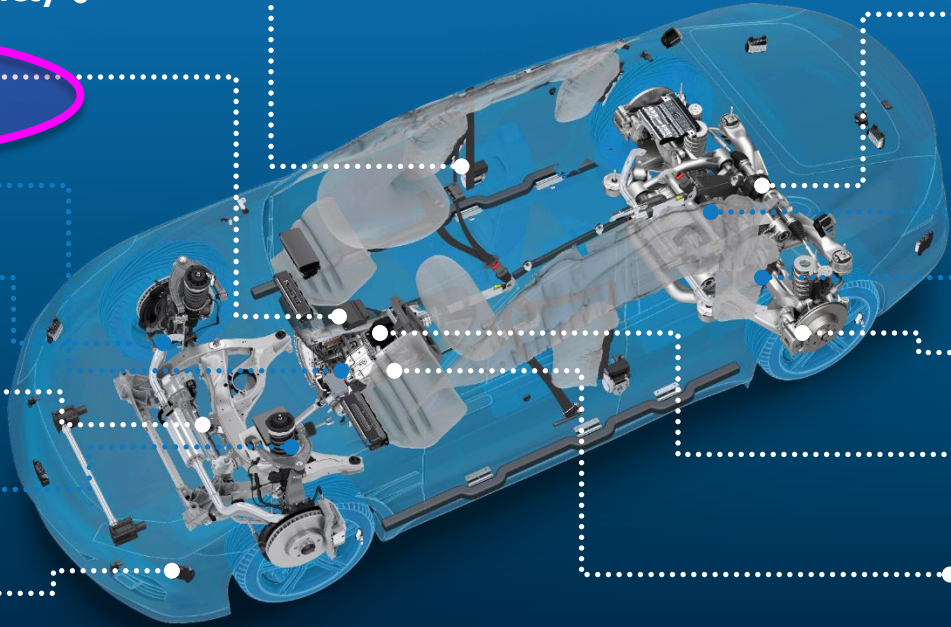
Axle Drives / Electric Axle Drives

Axle Systems

Braking Systems

Transmission Systems

Electronic Systems



Electrified Powertrain :

Vehicle Motion Control:

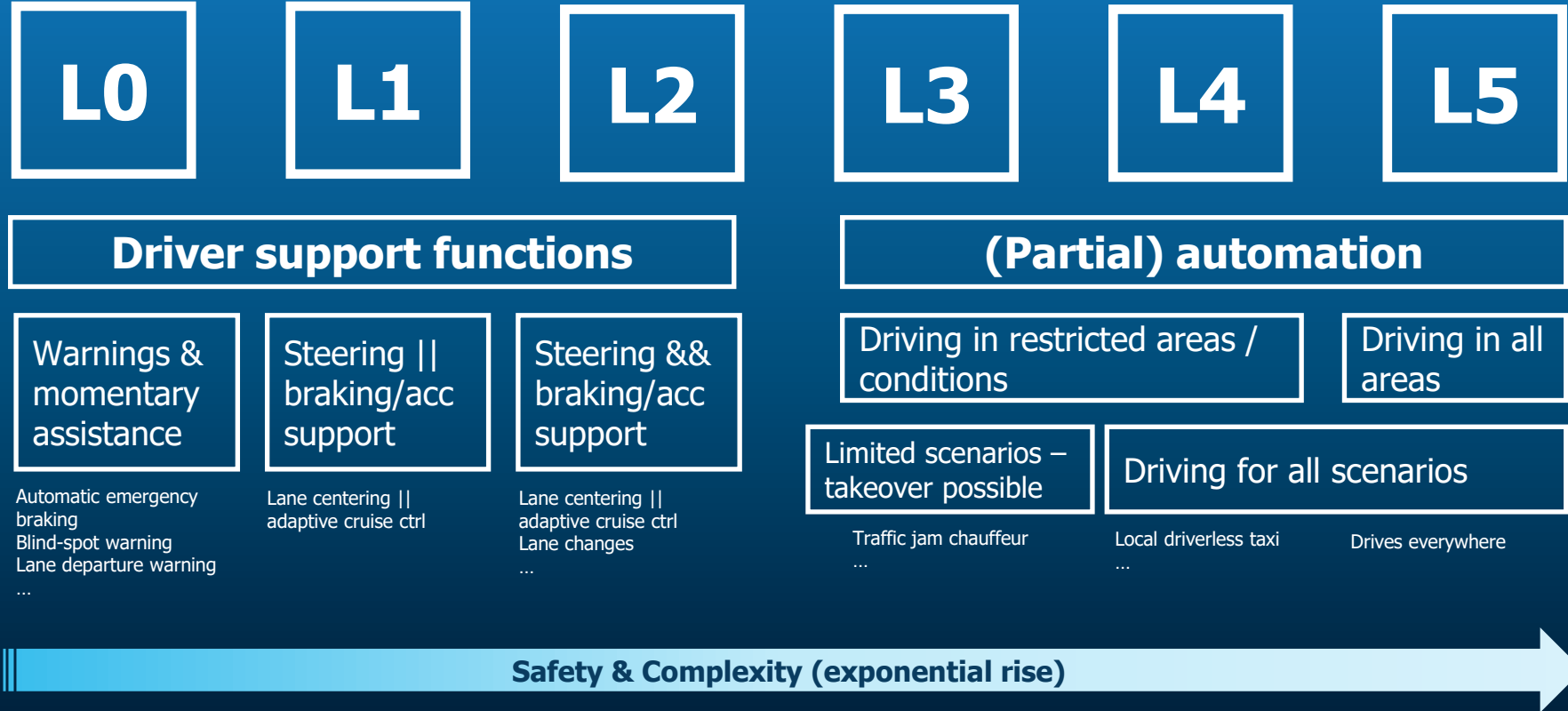
Automated Driving:

Integrated Safety:





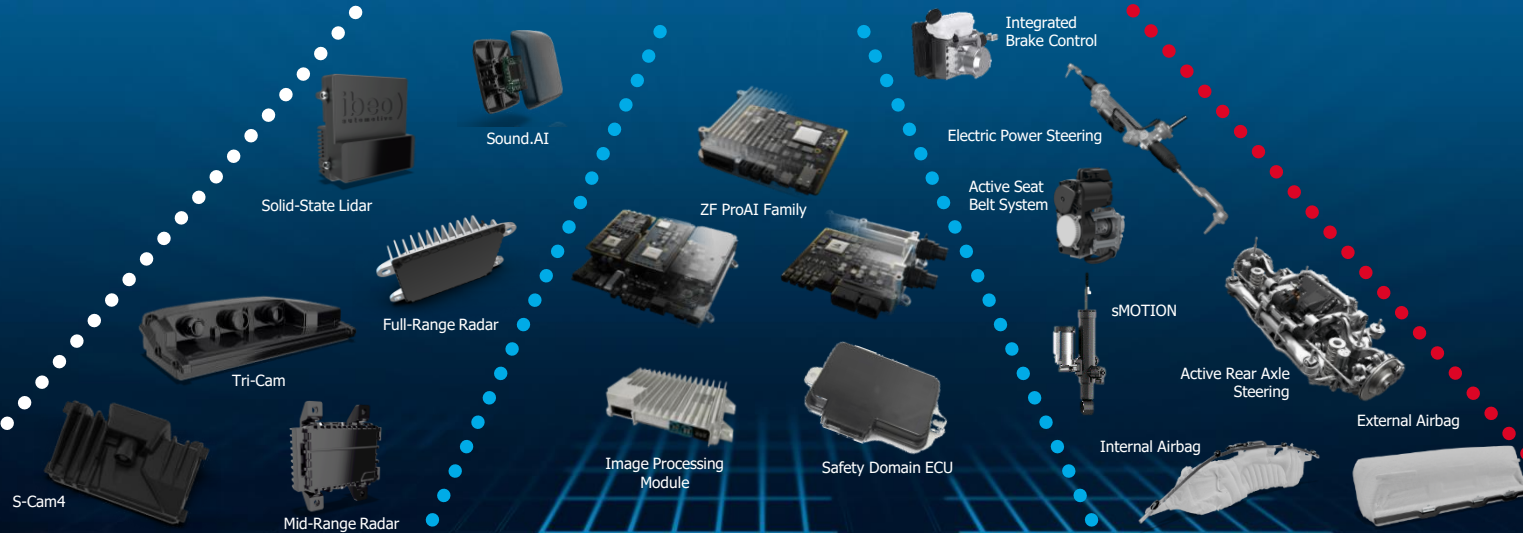
# SAE Levels for Driving Automation



\*SAE International = Society of Automotive Engineers

[https://www.sae.org/standards/content/j3016\\_201806/](https://www.sae.org/standards/content/j3016_201806/)

# Technology Paves The Way to Autonomous Driving



**See.**



**Think.**



**Act.**



# Sensor Example 2: 4-Dim Far Range Radar

Size 120 x 120 x 41 mm

Weight 550 g

Frequency 77 GHz

Channels 192

Cycle time 60 ms

Range 100 – 300 m

Doppler accuracy 0.01 m/s

Azimuth FoV 20 - 60°

Elevation FoV 15°

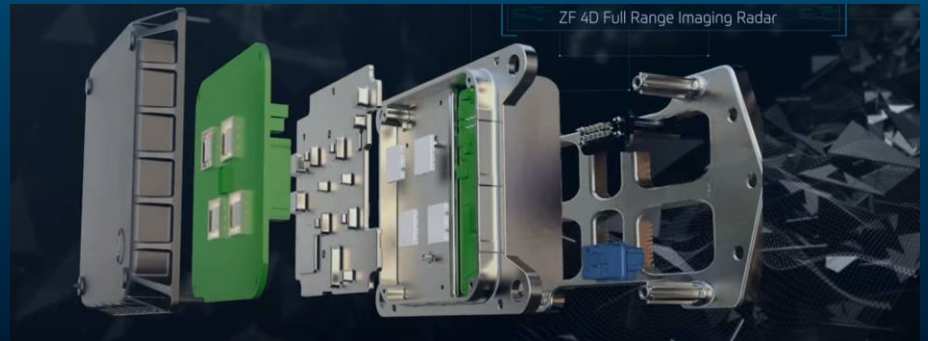
Angular resolution ~1°

Features

- Object tracking
- Object classification
- Free-space detection
- Auto-alignment

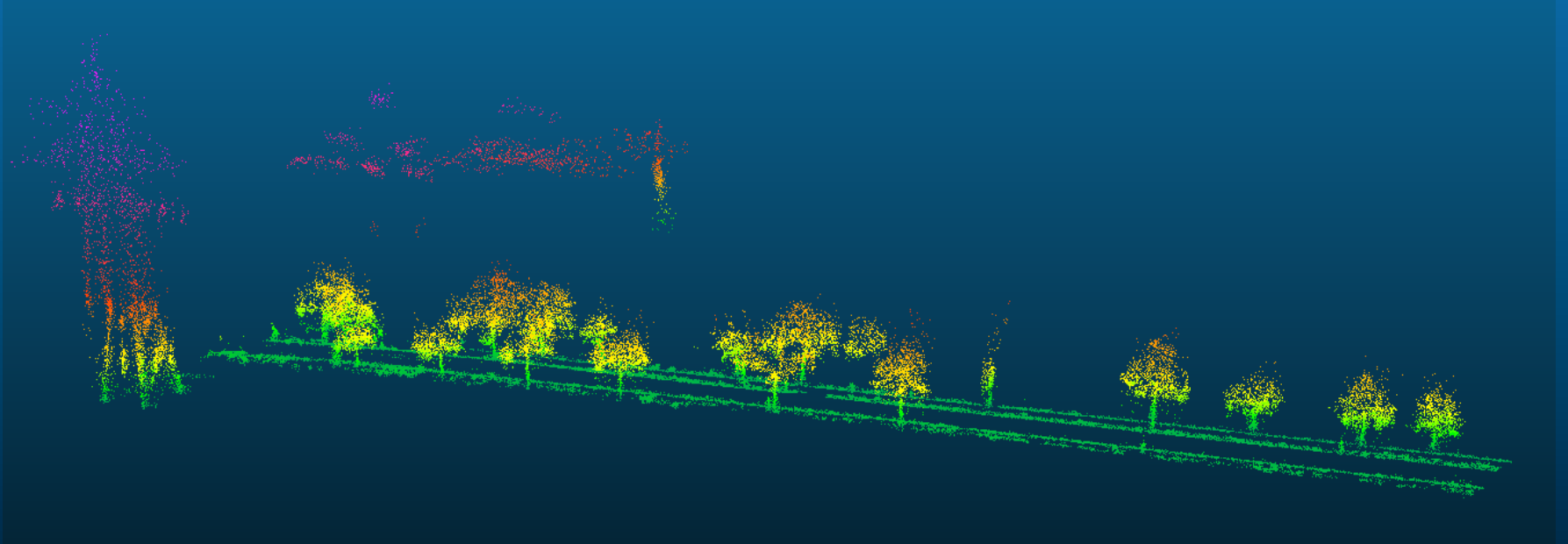
Use cases

- L2-L4 Automation
- Highway + urban scenarios



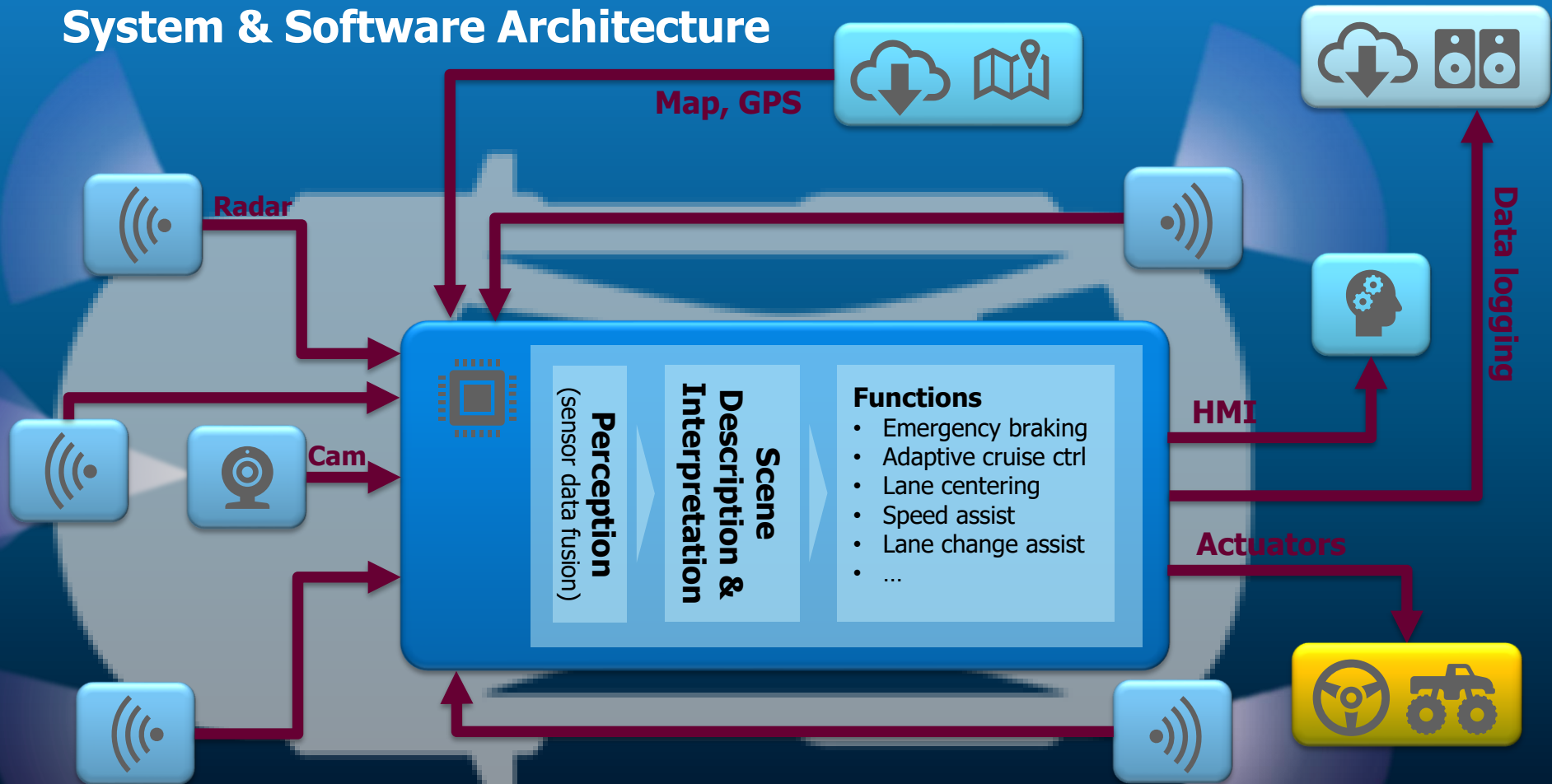
# Far Range Radar : Point Cloud Example

Static map of radar point cloud recorded along driving path



\*) Colour coding = height

# System & Software Architecture

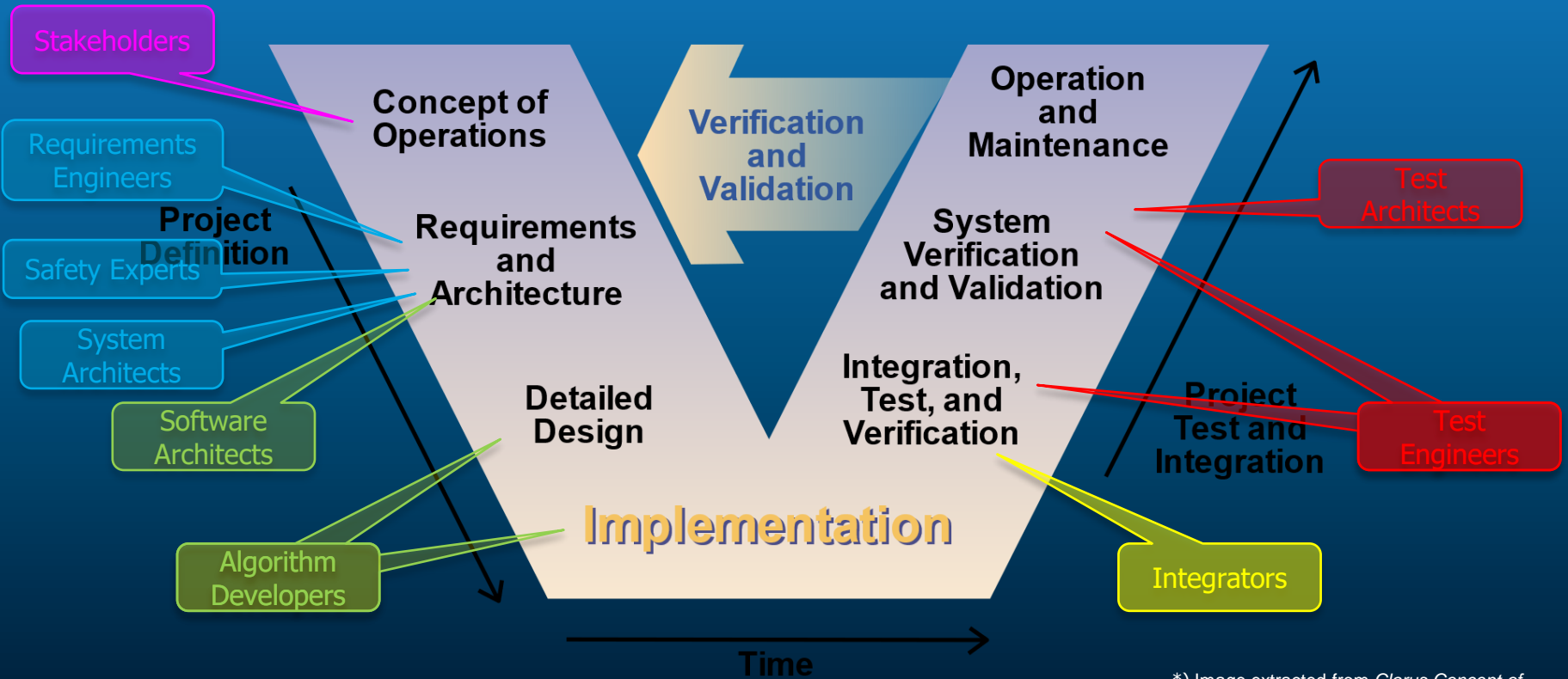


# Functions

- Route Following Assist
- Lane Change Assist
- Lane Centering
- Adaptive Cruise Ctrl
- Speed Assist
- Turn Assist
- Traffic Jam Assist
- Emergency Braking
- Emergency Stop
- Emergency Steering Support
- Automated Parking
- ...



# System & Software Development Process – V Model / ASPICE



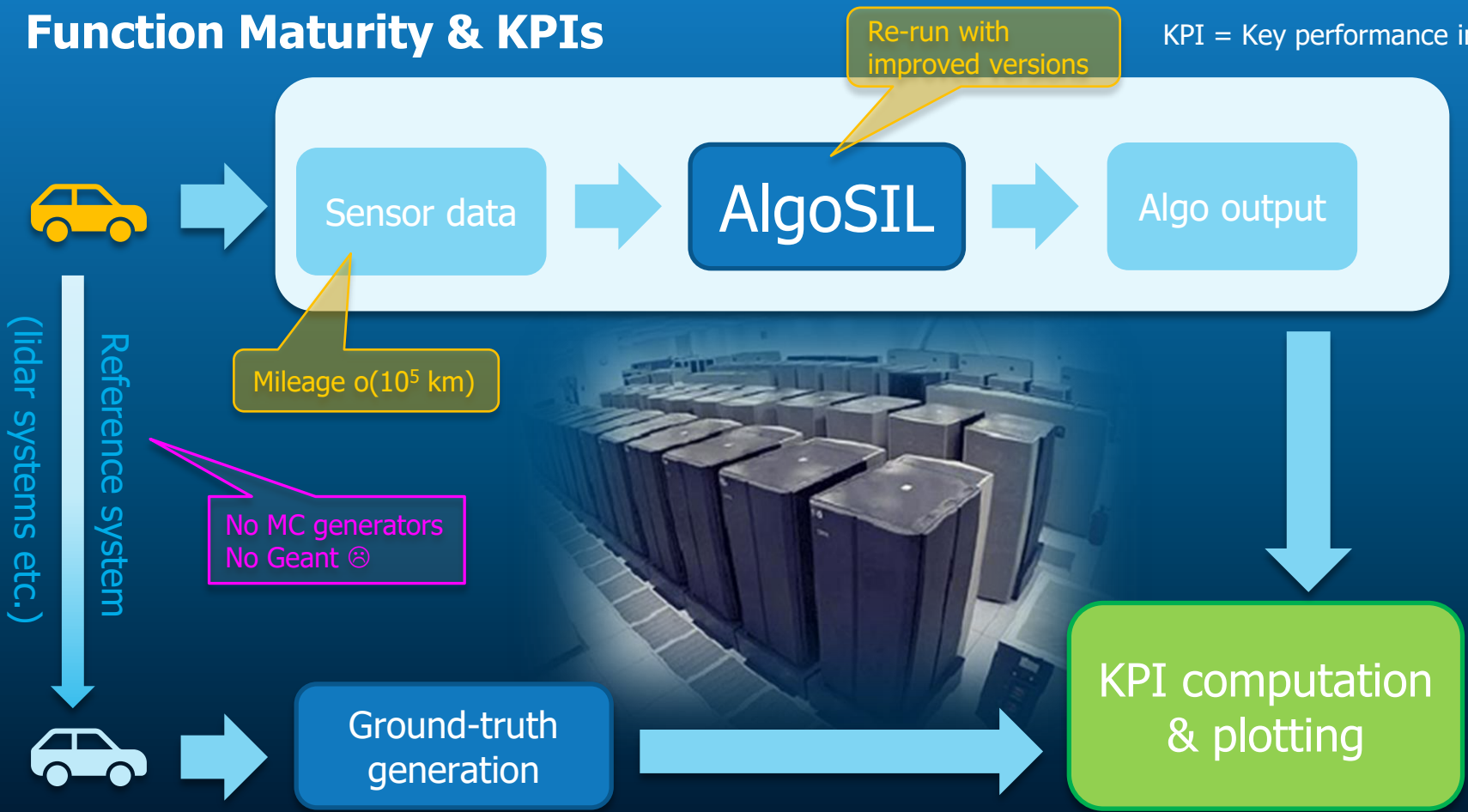
plus Mngmt, Project Leads, Team Leads, Function Owners, QM, Tooling Experts, ...

\*) Image extracted from *Clarus Concept of Operations*, Publication No. FHWA-JPO-05-072, Federal Highway Administration (FHWA), 2005



# Function Maturity & KPIs

KPI = Key performance indicator



# Function Maturity & KPIs

- Continuous monitoring of function performance during development phase
- Large statistics of open road data required to include complex scenarios and corner cases
- Better sensors and higher automation lead to tighter target maturity requirements → Big Data



# Conclusion

- Automotive Industries provide a thrilling working area for physicists with a lot of challenges
- Higher automation levels (L3, L4) are to be expected in the coming years – more challenges to come
- For Automated Driving many similarities to Particle Physics exist (sensor development, sensor data fusion, big data analysis, ...)

Come along!

[oliver.kind@zf.com](mailto:oliver.kind@zf.com)

# Back-up Slides

# Key Figures – Division U

## Global Footprint – Production, Development, and Sales

26 locations in 12 countries

23 Engineering centers in 11 countries

9 Manufacturing sites in 8 countries



**5,700**  
Employees



# ZF has an extensive portfolio of ADAS & AD products, technologies and competences



EuroNCAP /  
Safety Reg

L2+ / L3

Parking

## Driving Functions



## System Integration

ADAS.ai

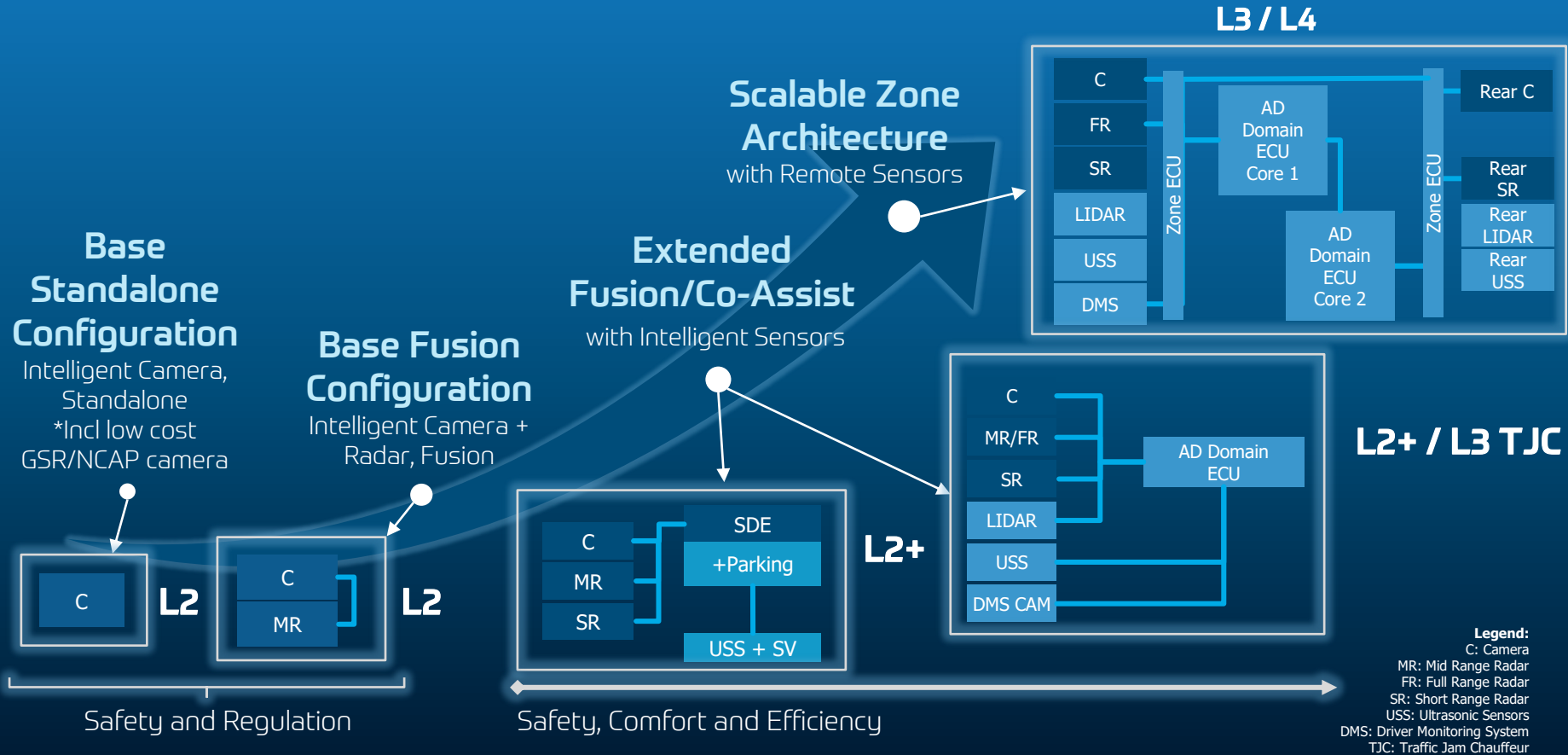
Cloud Solutions

Middleware SW

Testing and  
Validation

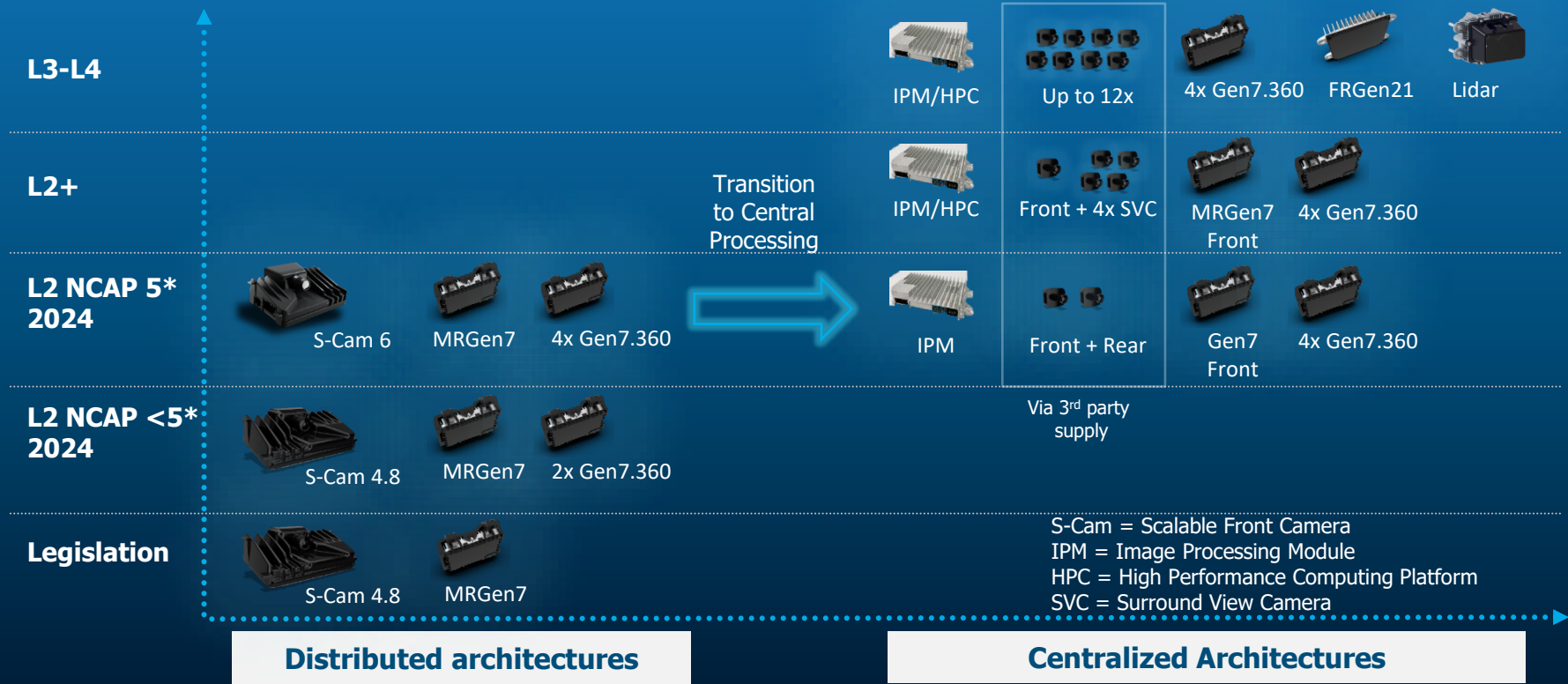


# ZF Functions can be deployed on a scleable system architecture



# ZF sensor portfolio covers the full functional range

## Overview of Div-U Sensor Portfolio





# ZF ProAI Range

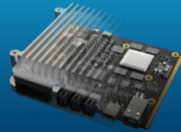
EMC  
CERTIFIED

## ZF ProAI Entry



Entry  
1 TOPS

## ZF ProAI Mid



Small Xavier S  
10-15 TOPS

## ZF ProAI High



Standard Xavier  
20-25 TOPS

## ZF ProAI Flex



3 Slots  
Modular Performance  
Up to 90 TOPS

## ZF ProAI RoboThink



Up to 600 TOPS  
Electromagnetic  
certification

Suitable for  
Mobility-as-a-Service  
applications

# ZF electrifies everything

## From bikes and cars to trucks and buses



# ZF Group is an e-mobility pioneer – more than 30 years of e-drive expertise for all major OEMs

**From 2023 onwards**  
Ongoing SOPs  
Electric Axle Drives



**2022**  
SOP 800 V  
Electric Axle Drives



**2,000,000  
E-Motors**

**2022**  
SOP Hybrid  
transmission



**2021**  
Further SOPs  
Electric Axle Drives



**2018**  
SOP Hybrid  
transmissions



**2018**  
SOPs  
first Electric Axle Drives



**2012**  
SOP Hybrid  
transmissions



**1989**  
Start Development  
Electric Drive Systems

**2008**  
SOP first  
Hybrid modules

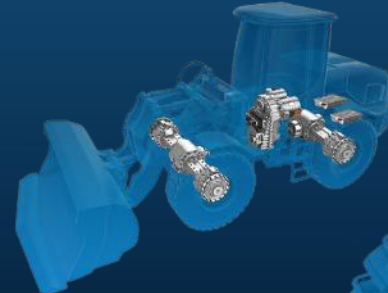
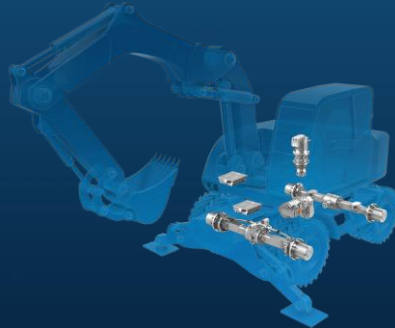


# Electrification Projects in the I-Division

**Electrical Truck Mixer**



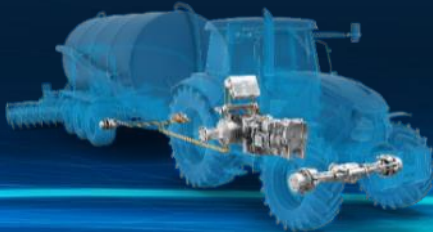
**Electrification Mobile Excavator and Wheel Loader**



**Hybrid Systems for Ships**



**Electrification Tractors, Implements and Compact Vehicles**



**Electrification  
Terminal Tractors**

# Division Car Chassis Technology

## Product Lines

### Chassis Components



#### Product Portfolio

- Tie Rods
- Stabilizer Links
- Control Arms
- Suspension and Cross-Axis Joints
- Wheel Carriers
- Plastics Technology
- Smart Components

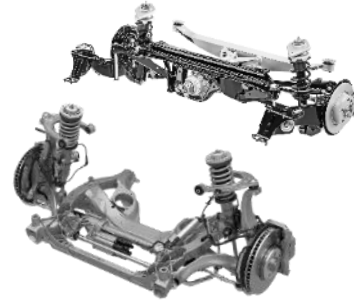
### Suspension Technology



#### Product Portfolio

- Damping Modules and Damping Systems
- Semi-Active Systems (CDC)
- Active Systems (sMOTION, eLEVEL)

### Chassis Systems & Modules



#### Product Portfolio

- Front and Rear Axle Systems
- Corner Modules

### Chassis Actuators



#### Product Portfolio

- Active Kinematics Control (AKC)
- Electromechanical Roll Control (ERC)
- Air Supply Unit & Compressors (ECAS)

# Sales Division Industrial Technology according to Business Units 2022

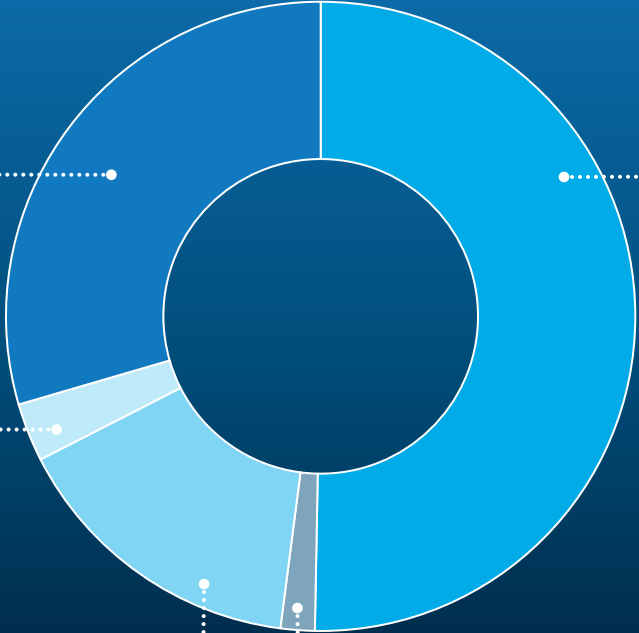
**Wind Power Technology & Industrial Drives**  
1,019.7 million €\*

**Off-Highway Systems & Test Systems**  
1,737.3 million €\*

**Aviation Technology**  
103.5 million €\*

**Marine & Special Driveline Technology**  
533.2 million €\*

**Components**  
60.5 million €\*



\*consolidated



# ZF Technology

## Rescue Connect

### Digital solutions for emergency services

- Networks and digitizes all emergency and rescue services in Europe
- For the first time, vehicles, equipment and people are all connected centrally
- Supports emergency management and decision-makers
- All products are specially designed for manufacturers of emergency vehicles, suppliers of rescue equipment and providers of operation-specific software
- Member of the IMBOS project



# Micro Mobility

## Product overview





# Wind Power Technology

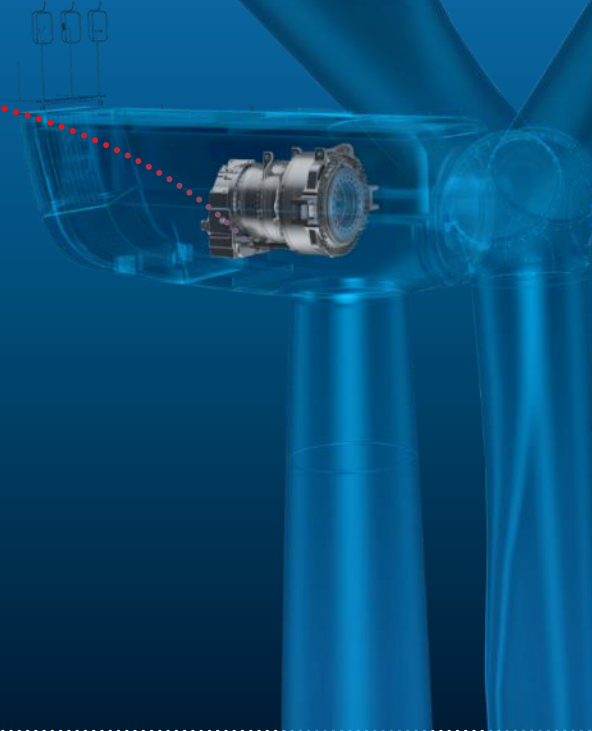
## Customized and special products

Gearboxes for small to large turbines

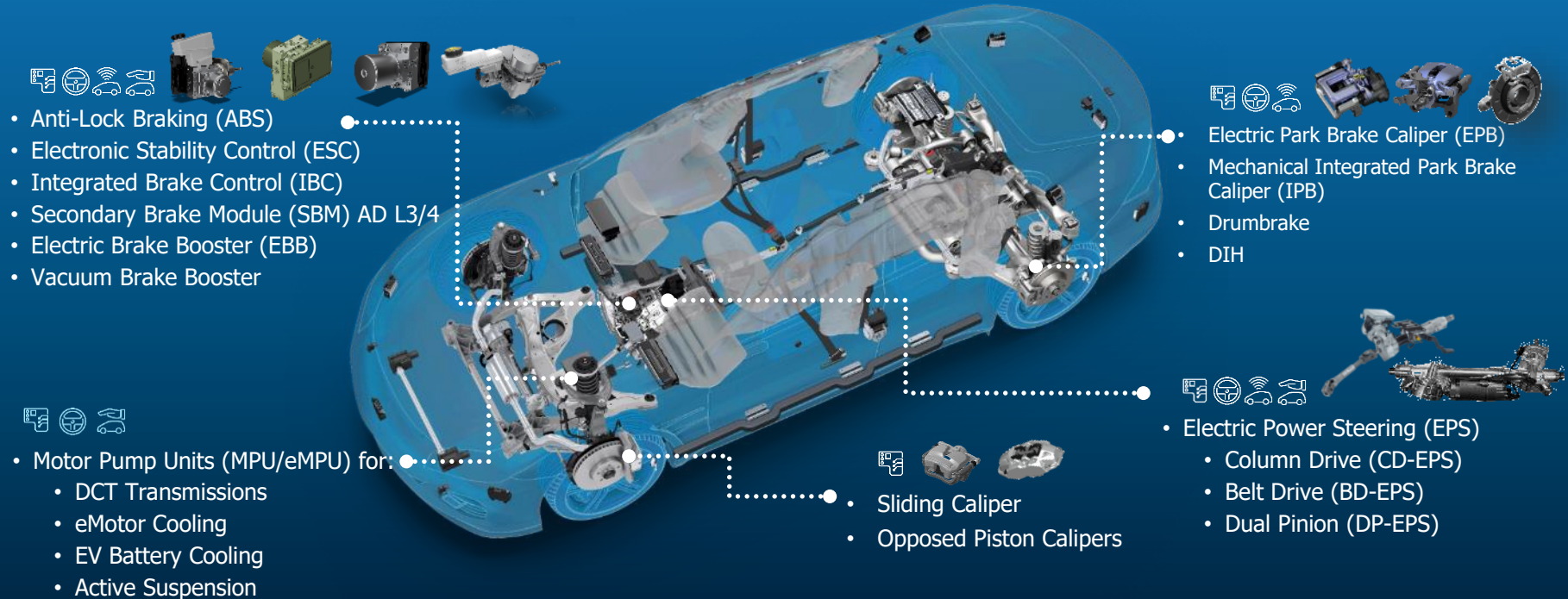


Onshore & offshore applications

Output range: from 2.0 MW up to 10.0 MW



# Division A is a key contributor to all critical technology and safety fields and paves way to automated driving



Electrified Powertrain :

Vehicle Motion Control:

Automated Driving:

Integrated Safety:



# Steer-by-Wire: New Technology Supporting Global Megatrends!



# SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	<ul style="list-style-type: none"> <li>• automatic emergency braking</li> <li>• blind spot warning</li> <li>• lane departure warning</li> </ul>	<ul style="list-style-type: none"> <li>• lane centering OR</li> <li>• adaptive cruise control</li> </ul>	<ul style="list-style-type: none"> <li>• lane centering AND</li> <li>• adaptive cruise control at the same time</li> </ul>	<ul style="list-style-type: none"> <li>• traffic jam chauffeur</li> </ul>	<ul style="list-style-type: none"> <li>• local driverless taxi</li> <li>• pedals/steering wheel may or may not be installed</li> </ul>	<ul style="list-style-type: none"> <li>• same as level 4, but feature can drive everywhere in all conditions</li> </ul>

For a more complete description, please download a free copy of SAE J3016: [https://www.sae.org/standards/content/J3016\\_201806/](https://www.sae.org/standards/content/J3016_201806/)

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