

# INTRODUCTION TO AUTOMATED DRIVING

Stefan Mathe, Catalin Golban

# Introduction to automated driving

## Intro and logistics

- ▶ Who we are?
  - ▶ Short intro
- ▶ Expectations
  - ▶ From students
  - ▶ From the Bosch team
    - Attendance
      - Minimum 8 attendances mandatory, recommended maximum of course 😊
    - Seminars
      - Laptops discussion
      - 4 attendances mandatory
- ▶ Contact persons at UBB?
- ▶ Exam hints
- ▶ Bosch contacts: [Catalin.Golban@ro.bosch.com](mailto:Catalin.Golban@ro.bosch.com), [Stefan.Mathe@ro.bosch.com](mailto:Stefan.Mathe@ro.bosch.com)

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1. Introduction
2. Vision of a highly autonomous vehicle
3. Levels of automation
4. Architecture for autonomous vehicles
5. Structure of the course
6. About Bosch

# INTRODUCTION

# Future Mobility

## Electrified, automated and connected



costs hybrid e-motor  
eBike power electronics

## electrified

plug-in eScooter range  
fun-to-drive battery  
charging infrastructure

legislation driver assistance  
emergency braking autopilot

## automated

highway-pilot sensors  
redundancy electric steering  
valet parking

electronic horizon  
smartphone integration

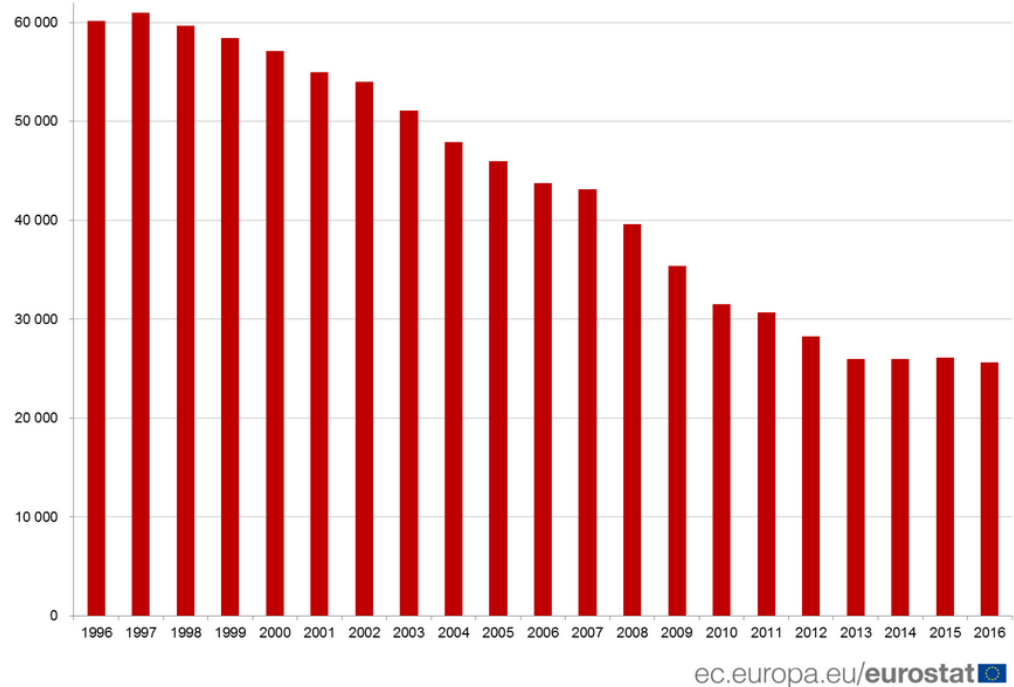
## connected

eCall cloud  
services fleet management  
car2car augmented reality

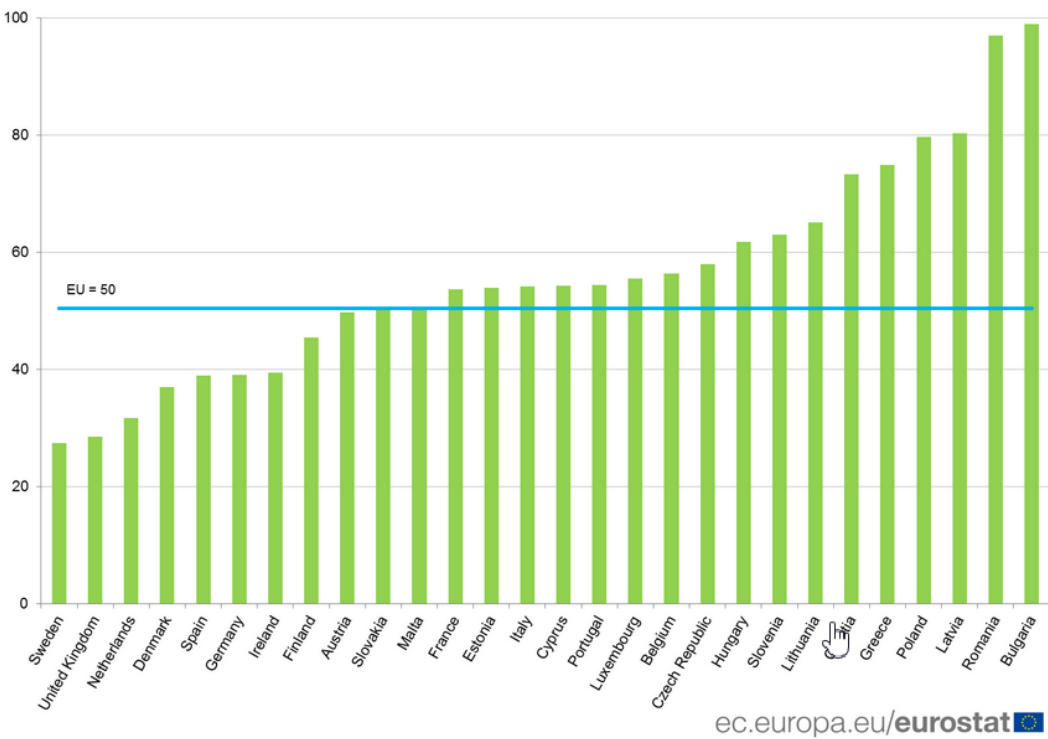
# Introduction to automated driving

## Technology saves lives

Road traffic victims in the European Union, 1996-2016



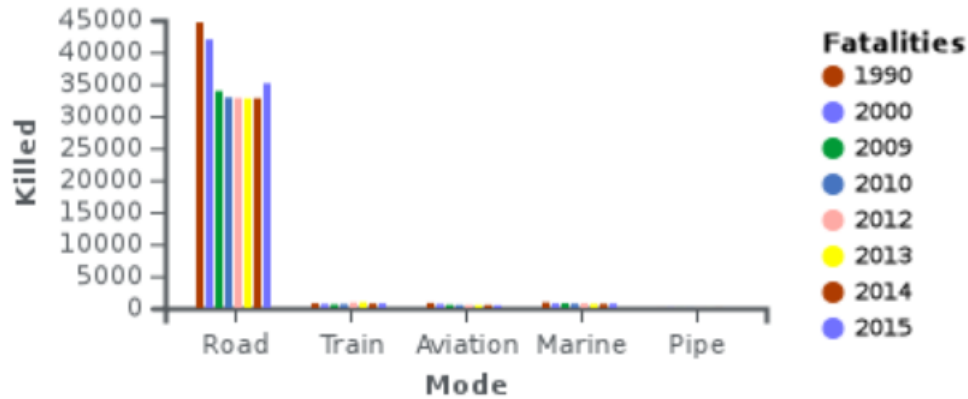
Road traffic victims per million inhabitants in the EU Member States, 2016



# Introduction to automated driving

## Technology saves lives

In the United States, most fatalities are generated by road vehicles.



[https://en.wikipedia.org/wiki/Transportation\\_safety\\_in\\_the\\_United\\_States](https://en.wikipedia.org/wiki/Transportation_safety_in_the_United_States)



# Introduction to automated driving

## Milestones in road safety

World's first antilock braking system



World's first traction control system



Predictive emergency braking system



Lane change assist with mid-range radar



Fully automated driving



World's first airbag control unit



World's first ESP®



Regenerative braking with ESP® hev



Active pedestrian protection with stereo video camera



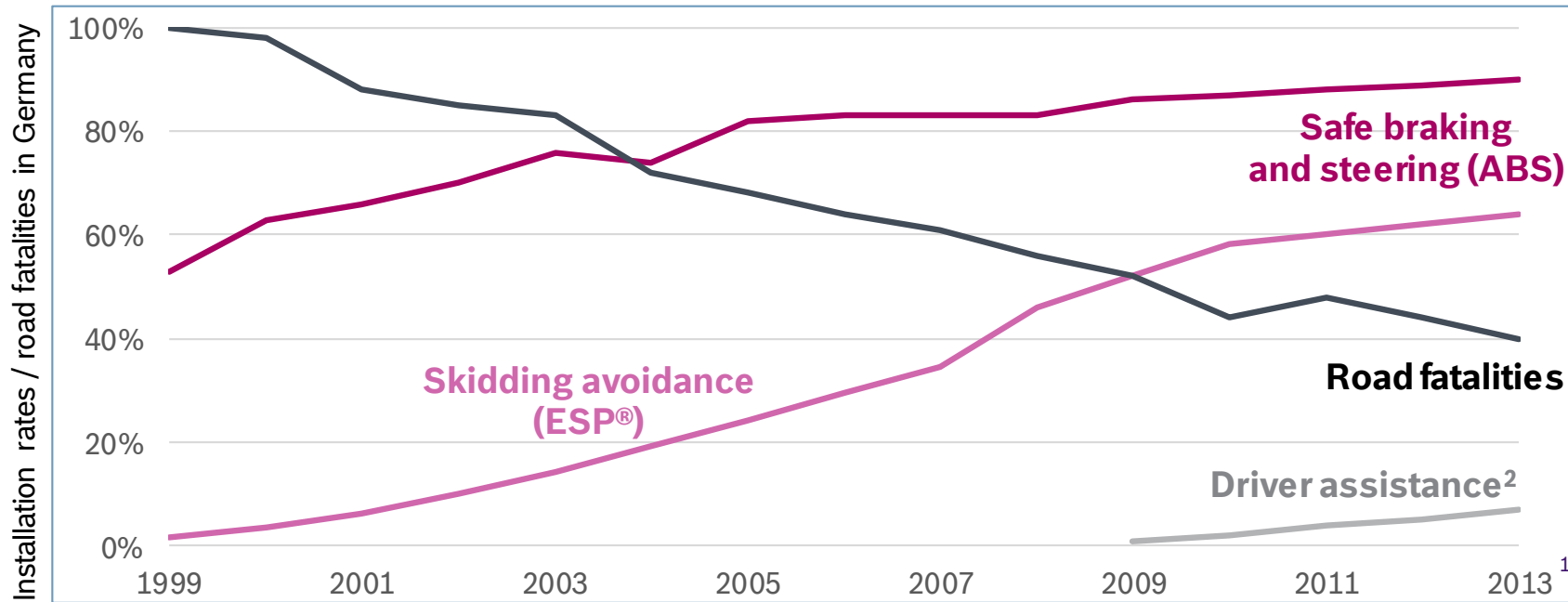
iBooster

# Road safety

## Influence of driver assistance

Number of road fatalities reduced by 60% within last 14 years

- ▶ 90% of all car accidents involving injury are caused by human error
- ▶ Introduction of further driver assistance systems will amplify positive trend



Source: Bosch, DAT, BAST. Based on total vehicle fleet.

<sup>1</sup> Figures estimated

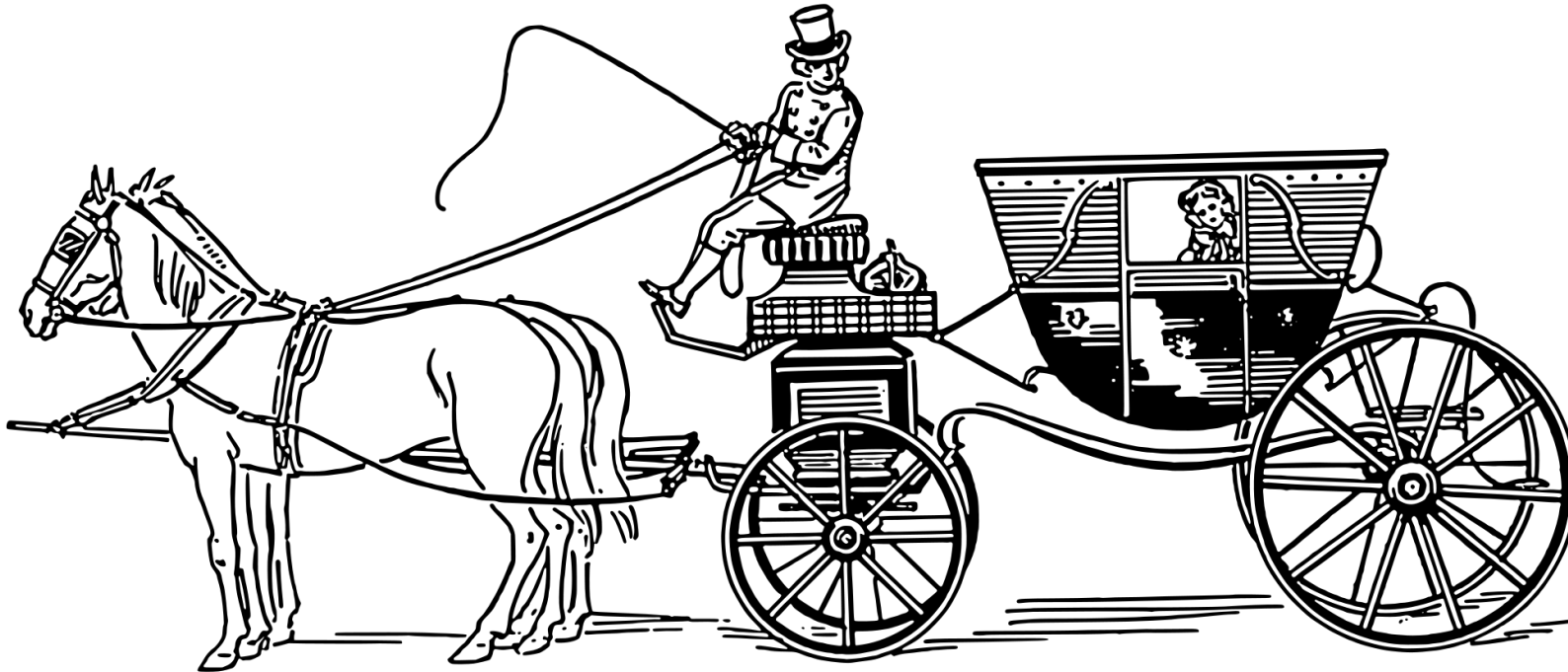
<sup>2</sup> ACC and lane keeping support only

# VISION OF A HIGHLY AUTONOMOUS VEHICLE

# Introduction to automated driving

## Technology progress & society

- "I believe in the horse. The automobile is a temporary appearance" - Wilhelm II, Emperor of Germany, 1916



# Example of a highly autonomous vehicle

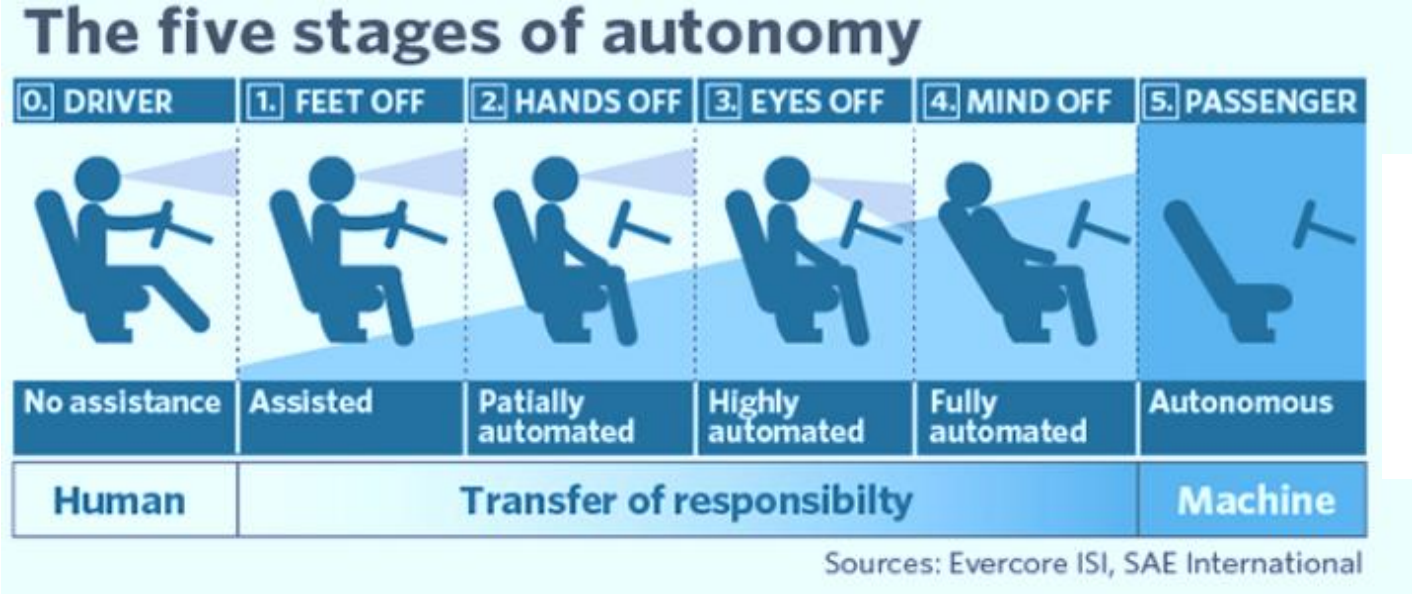
<https://www.youtube.com/watch?v=2i-t0C7RQWM>



# LEVELS OF AUTOMATION

# Introduction to automated driving

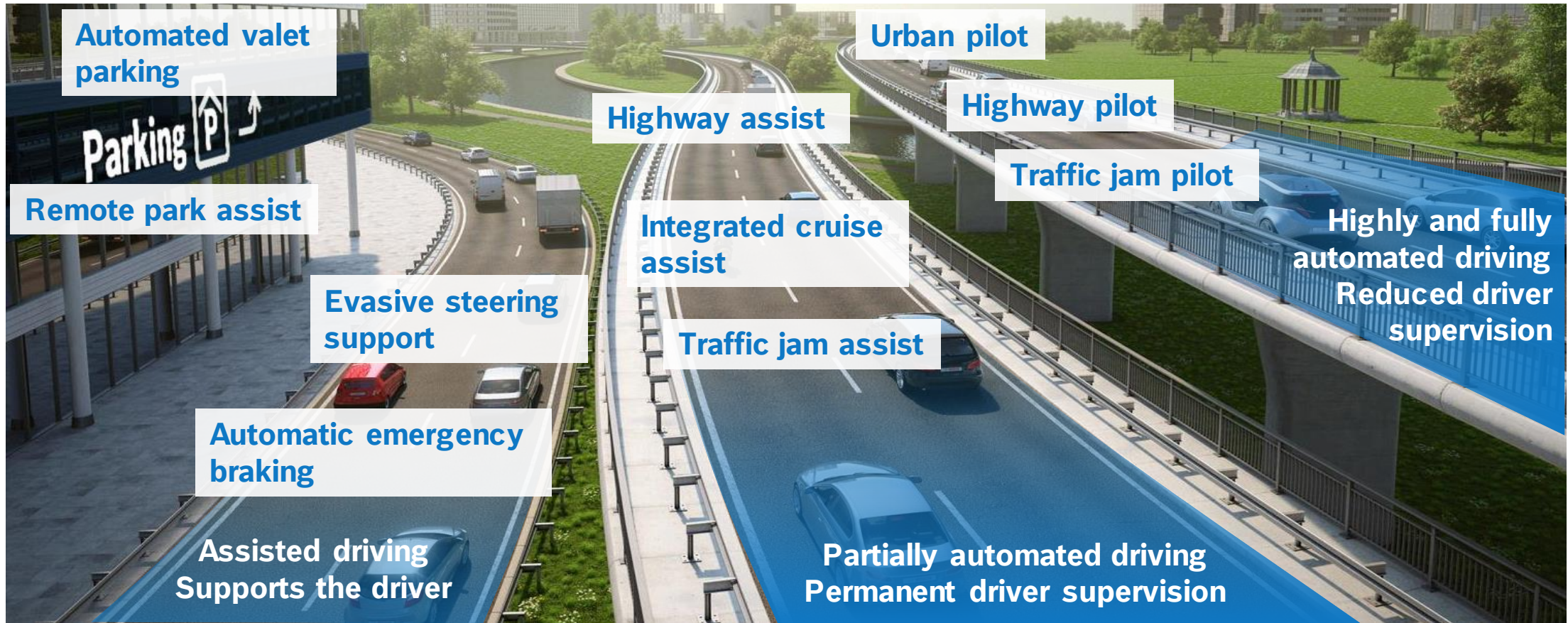
## Levels of automation





# Introduction to automated driving

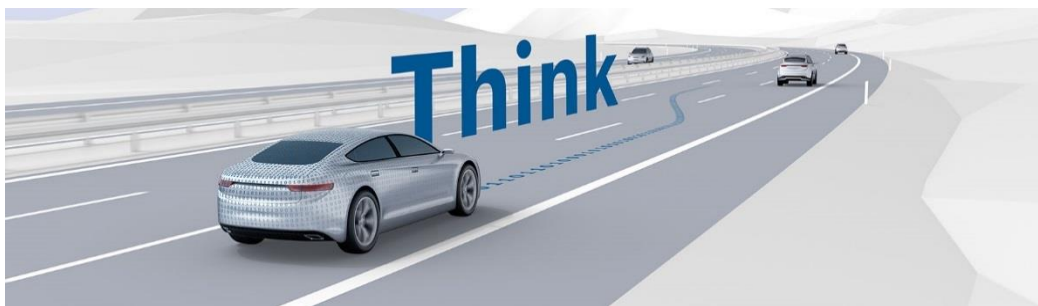
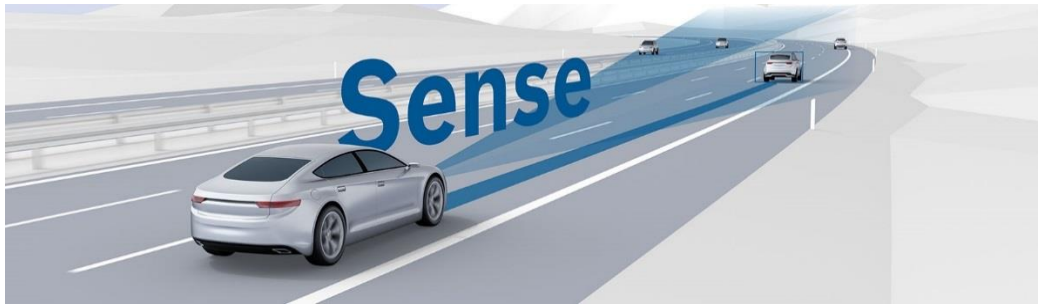
## Roadmap Highly Automated Driving Functions



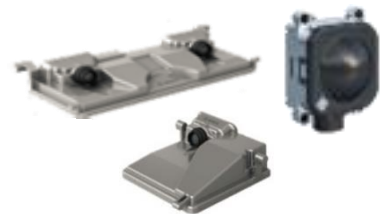


# Introduction to automated driving

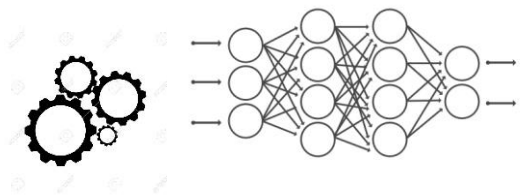
Sense -> think -> act



Sensors



Algorithms

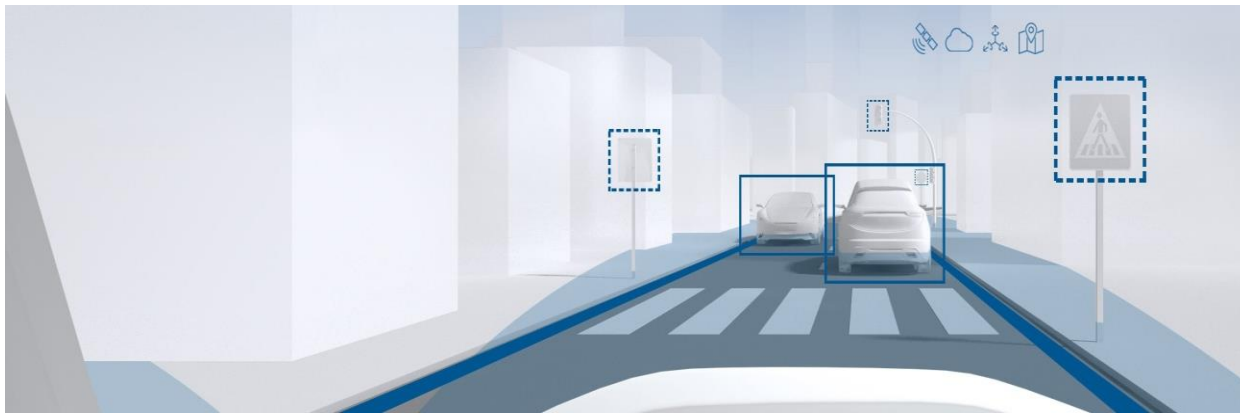


Steering system



# Introduction to automated driving

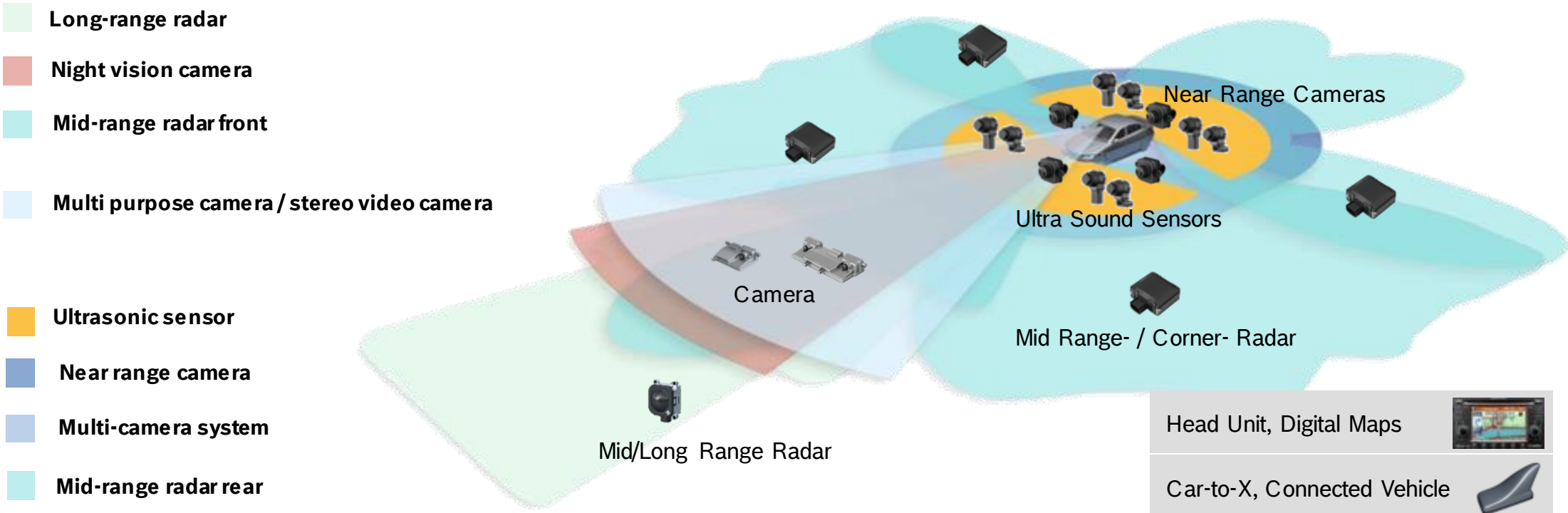
## Sensing / perception



- ▶ Sensors for environment understanding
  - ▶ Objects
  - ▶ Infrastructure elements
- ▶ Mapping & localisation

# Introduction to automated driving

## Bosch sensors portfolio

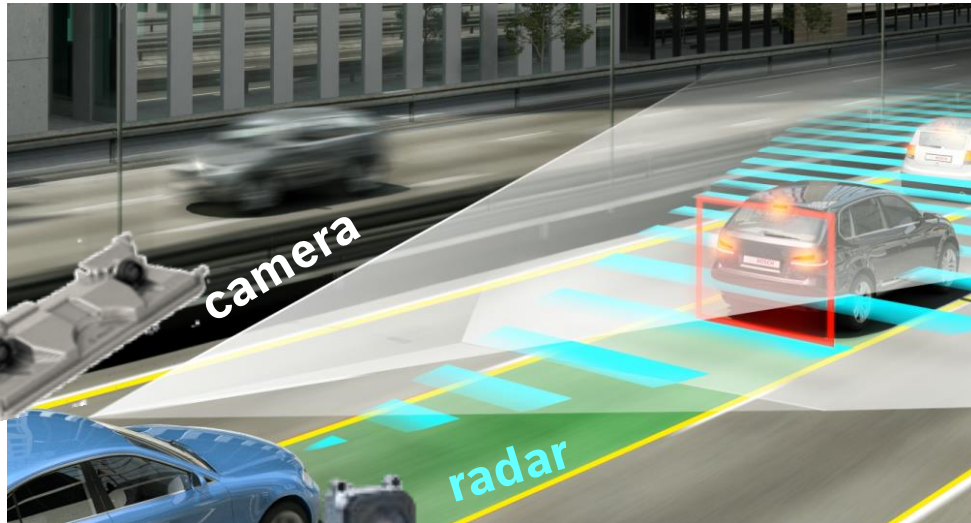


# Bosch Engineering Center Cluj

## Automated driving activities



SOFTWARE ENGINEERING



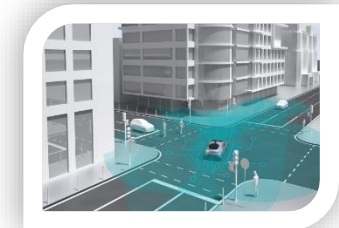
Radar Systems



Video Systems



Connectivity



Central processing unit



Ultrasonic Systems



Electric Power Steering



# State of the art

## Hudge investments

### The Building Blocks of Autonomy

Prepared by  VISION SYSTEMS INTELLIGENCE



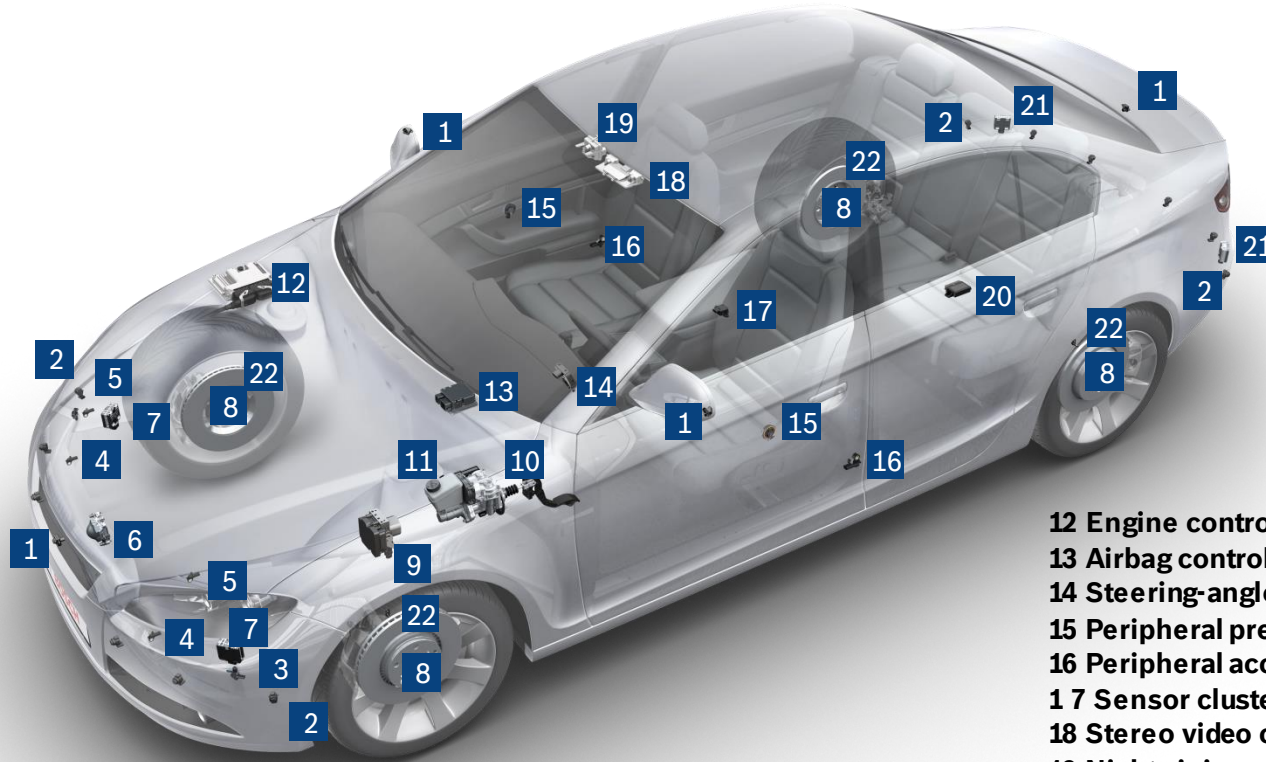
Copyright 2016 – Vision Systems Intelligence, LLC.

# ARCHITECTURE FOR AUTONOMOUS VEHICLES

# Chassis Systems Control

## Product portfolio

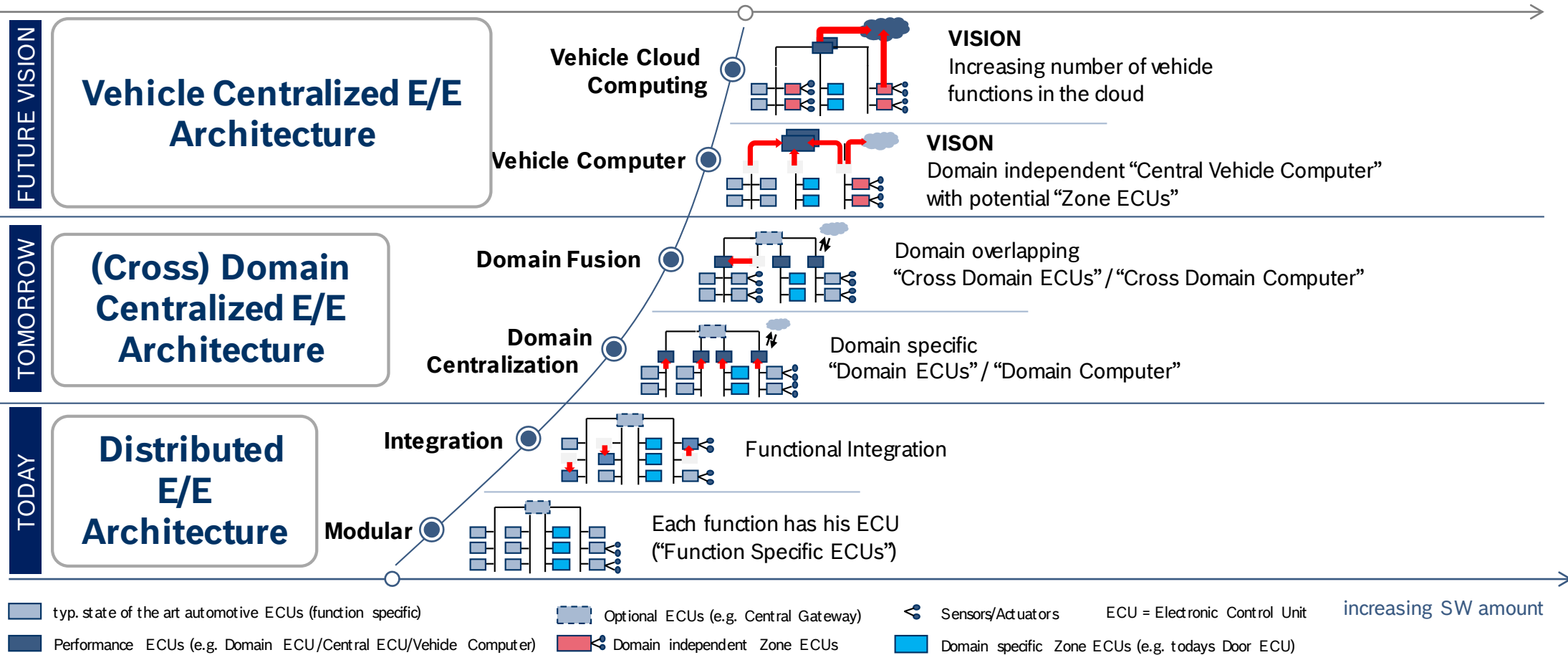
- 1 Near-range camera
- 2 Ultrasonic sensors
- 3 Pressure tube sensor
- 4 Pedestrian contact sensor
- 5 Upfront sensor
- 6 Long-range radar sensor
- 7 Mid-range radar sensor
- 8 Brake disc
- 9 ESP® hydraulic unit with attached control unit
- 10 iBooster
- 11 Brake master cylinder with reservoir



- 12 Engine control unit
- 13 Airbag control unit/ integrated safety unit
- 14 Steering-angle sensor
- 15 Peripheral pressure sensor
- 16 Peripheral acceleration sensor
- 17 Sensor cluster
- 18 Stereo video camera
- 19 Night vision camera
- 20 ECU for park pilot
- 21 Mid-range radar sensor
- 22 Wheel-speed sensor

# Roadmap E/E architecture

## Next steps in shorter timeframe



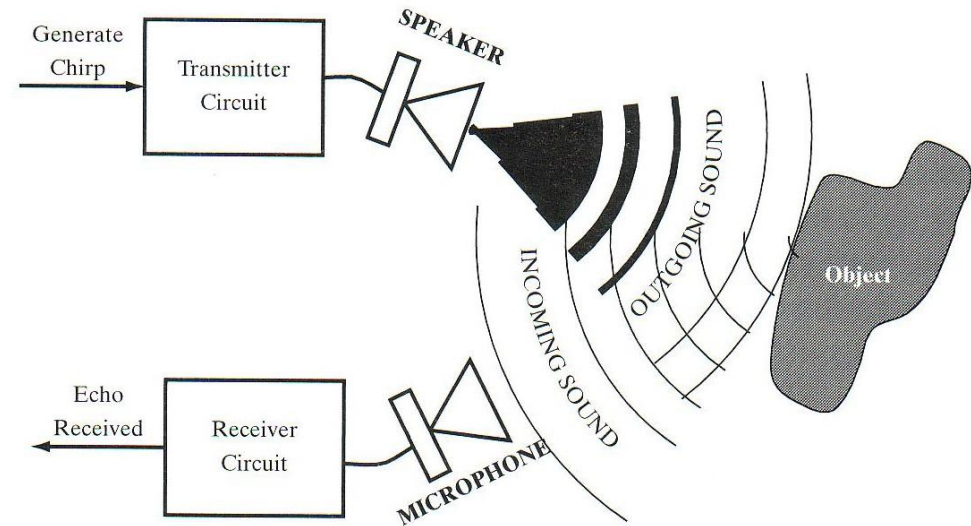


# STRUCTURE OF THE COURSE

# Introduction to automated driving

## Ultrasonic sensors

Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	<b>Ultrasonic</b>	
3/15/2019	Radar	Radar
3/22/2019	Video 1: intro	
3/29/2019	Video 2: disparity and flow	Video
4/5/2019	Video 3: 3D geometry	
4/12/2019	Deep Learning 1	Video
4/19/2019	Deep Learning 2	
4/26/2019	Easter holiday	
5/3/2019	Deep Learning 3	Deep Learning 1
5/10/2019	Deep Learning 4	
5/17/2019	Tracking and Sensors	
5/24/2019	Data Fusion	Deep Learning 2
5/31/2019	Connectivity overview, technology & frameworks	
6/7/2019	Connectivity statistics & data analytics	Deep Learning 3
6/7/2019	Exam and office hours	



# Introduction to automated driving

## Radar sensors

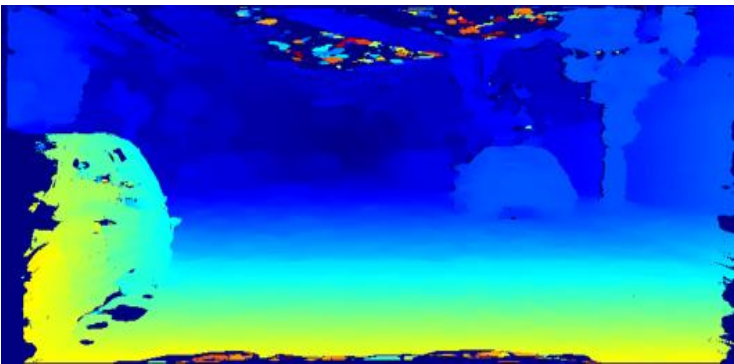
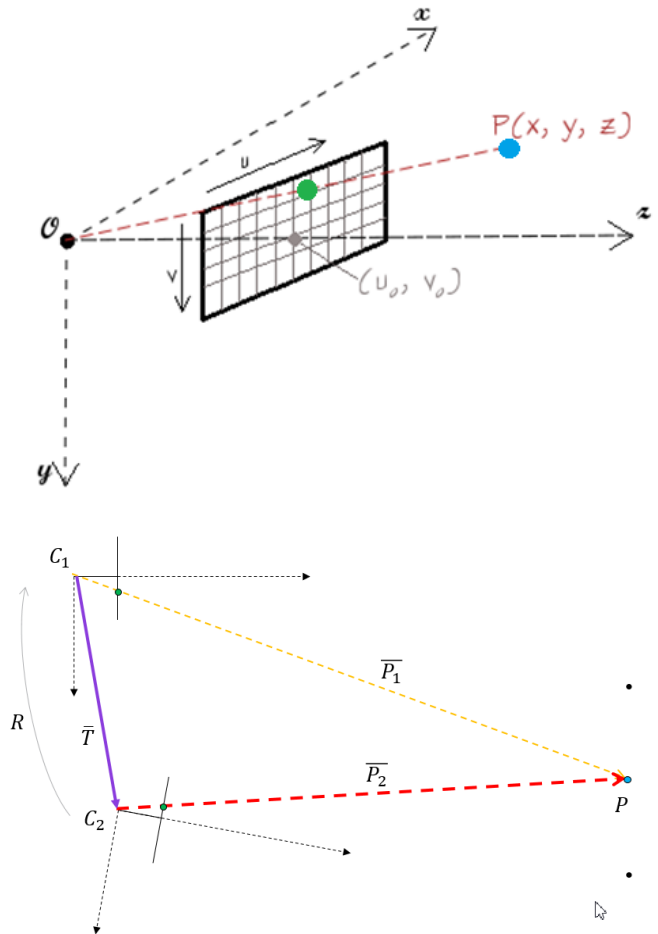
Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	Ultrasonic	
3/15/2019	<b>Radar</b>	<b>Radar</b>
3/22/2019	Video 1: intro	
3/29/2019	Video 2: disparity and flow	Video
4/5/2019	Video 3: 3D geometry	
4/12/2019	Deep Learning 1	Video
4/19/2019	Deep Learning 2	
4/26/2019	Easter holiday	
5/3/2019	Deep Learning 3	Deep Learning 1
5/10/2019	Deep Learning 4	
5/17/2019	Tracking and Sensors	
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# Introduction to automated driving

## Video sensors

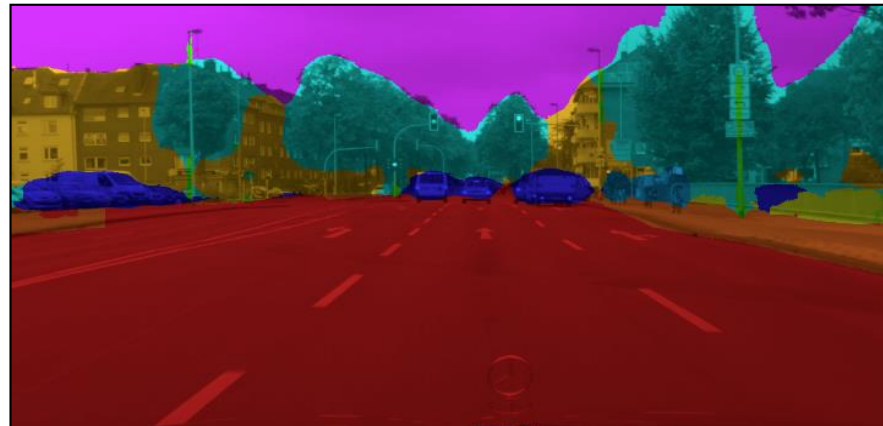
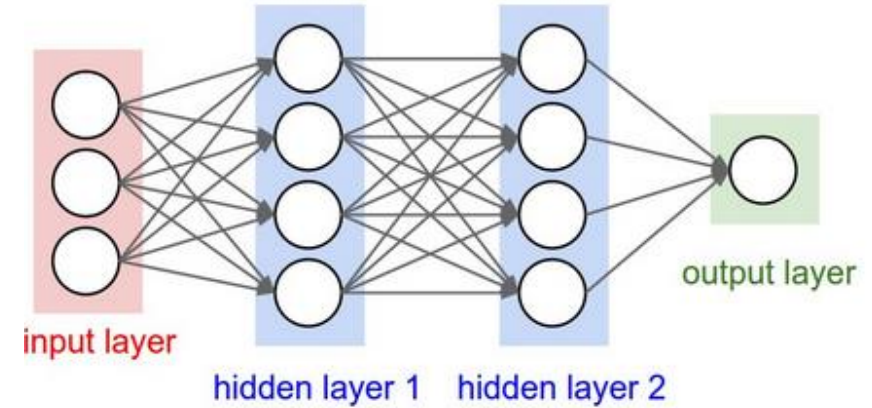
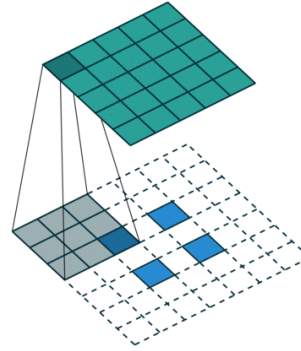
Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	Ultrasonic	
3/15/2019	Radar	Radar
3/22/2019	<b>Video 1: introduction</b>	
3/29/2019	<b>Video 2: disparity and optical flow</b>	<b>Video</b>
4/5/2019	<b>Video 3: 3D geometry</b>	
4/12/2019	Deep Learning 1	<b>Video</b>
4/19/2019	Deep Learning 2	
4/26/2019	Easter holiday	
5/3/2019	Deep Learning 3	Deep Learning 1
5/10/2019	Deep Learning 4	
5/17/2019	Tracking and Sensors Data Fusion	Deep Learning 2
5/24/2019	Connectivity overview, technology & frameworks	
5/31/2019	Connectivity statistics & data analytics	Deep Learning 3
6/7/2019	Exam and office hours	



# Introduction to automated driving

## Deep learning and convolutional neural networks

Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	Ultrasonic	
3/15/2019	Radar	Radar
3/22/2019	Video 1: introduction	
	Video 2: disparity and optical flow	
3/29/2019	Video 3: 3D geometry	Video
4/5/2019	Video 3: 3D geometry	
4/12/2019	<b>Deep Learning 1</b>	Video
4/19/2019	<b>Deep Learning 2</b>	
4/26/2019	Easter holiday	
5/3/2019	<b>Deep Learning 3</b>	<b>Deep Learning 1</b>
5/10/2019	<b>Deep Learning 4</b>	
5/17/2019	Tracking and Sensors	
	Data Fusion	<b>Deep Learning 2</b>
5/24/2019	Connectivity overview, technology & frameworks	
	Connectivity statistics & data analytics	
5/31/2019	Exam and office hours	<b>Deep Learning 3</b>
6/7/2019		

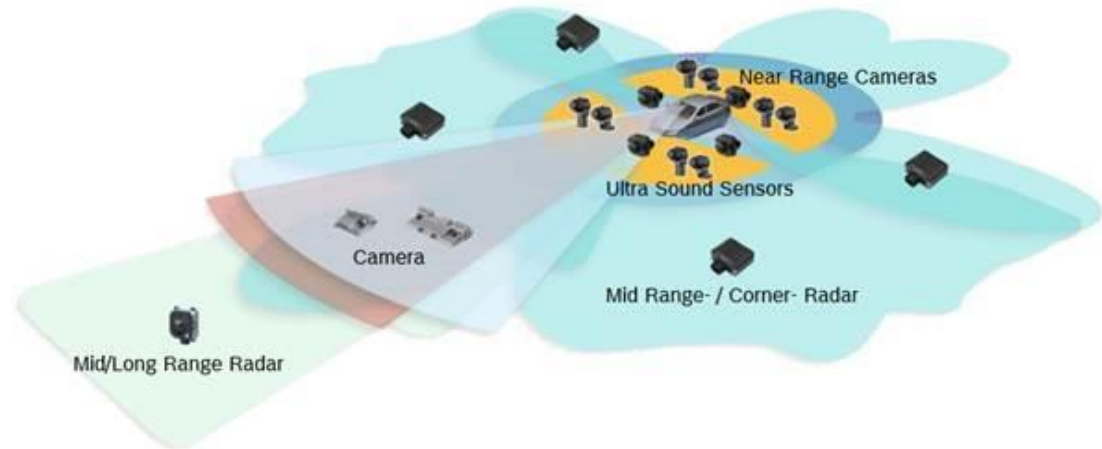




# Introduction to automated driving

## Tracking and data fusion

Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	Ultrasonic	
3/15/2019	Radar	Radar
3/22/2019	Video 1: intro	
3/29/2019	Video 2: disparity and flow	Video
4/5/2019	Video 3: 3D geometry	
4/12/2019	Deep Learning 1	Video
4/19/2019	Deep Learning 2	
4/26/2019	Easter holiday	
5/3/2019	Deep Learning 3	Deep Learning 1
5/10/2019	Deep Learning 4	
5/17/2019	<b>Tracking and Sensors Data Fusion</b>	Deep Learning 2
5/24/2019	Connectivity overview, technology & frameworks	
5/31/2019	Connectivity statistics & data analytics	Deep Learning 3
6/7/2019	Exam and office hours	



### Prediction

$$\hat{x}_t^- = A\hat{x}_{t-1} + Bu_{t-1}$$

$$P_t^- = AP_{t-1}A^T + Q_t$$

### Update

$$\hat{x}_t = \hat{x}_t^- + K_t(y_t - H\hat{x}_t^-)$$

$$K_t = \frac{P_t^- H^T}{HP_t^- H^T + R_t}$$

$$P_t = (I - K_t H)P_t^-$$

# Introduction to automated driving

## Connectivity, cloud and data analytics

Date	Course Topic	Seminar Topic
3/1/2019	Intro	
3/8/2019	Ultrasonic	
3/15/2019	Radar	Radar
3/22/2019	Video 1: intro	
3/29/2019	Video 2: disparity and flow	Video
4/5/2019	Video 3: 3D geometry	
4/12/2019	Deep Learning 1	Video
4/19/2019	Deep Learning 2	
4/26/2019	Easter holiday	
5/3/2019	Deep Learning 3	Deep Learning 1
5/10/2019	Deep Learning 4	
5/17/2019	Tracking and Sensors Data Fusion	Deep Learning 2
5/24/2019	<b>Connectivity overview, technology &amp; frameworks Connectivity statistics &amp; data analytics</b>	
5/31/2019		Deep Learning 3
6/7/2019	Exam and office hours	



# ABOUT BOSCH



# Bosch – a global network



- ▶ The **390,000<sup>1</sup>** Bosch associates make these solutions possible.
- ▶ Bosch has four business sectors, with more than 440<sup>1</sup> subsidiary companies and regional subsidiaries in some 60<sup>1</sup> countries. Including sales and service partners, Bosch's global manufacturing and sales network covers nearly every country in the world.

# Bosch – a global network

## Business sectors

**Mobility Solutions**



**Industrial  
Technology**



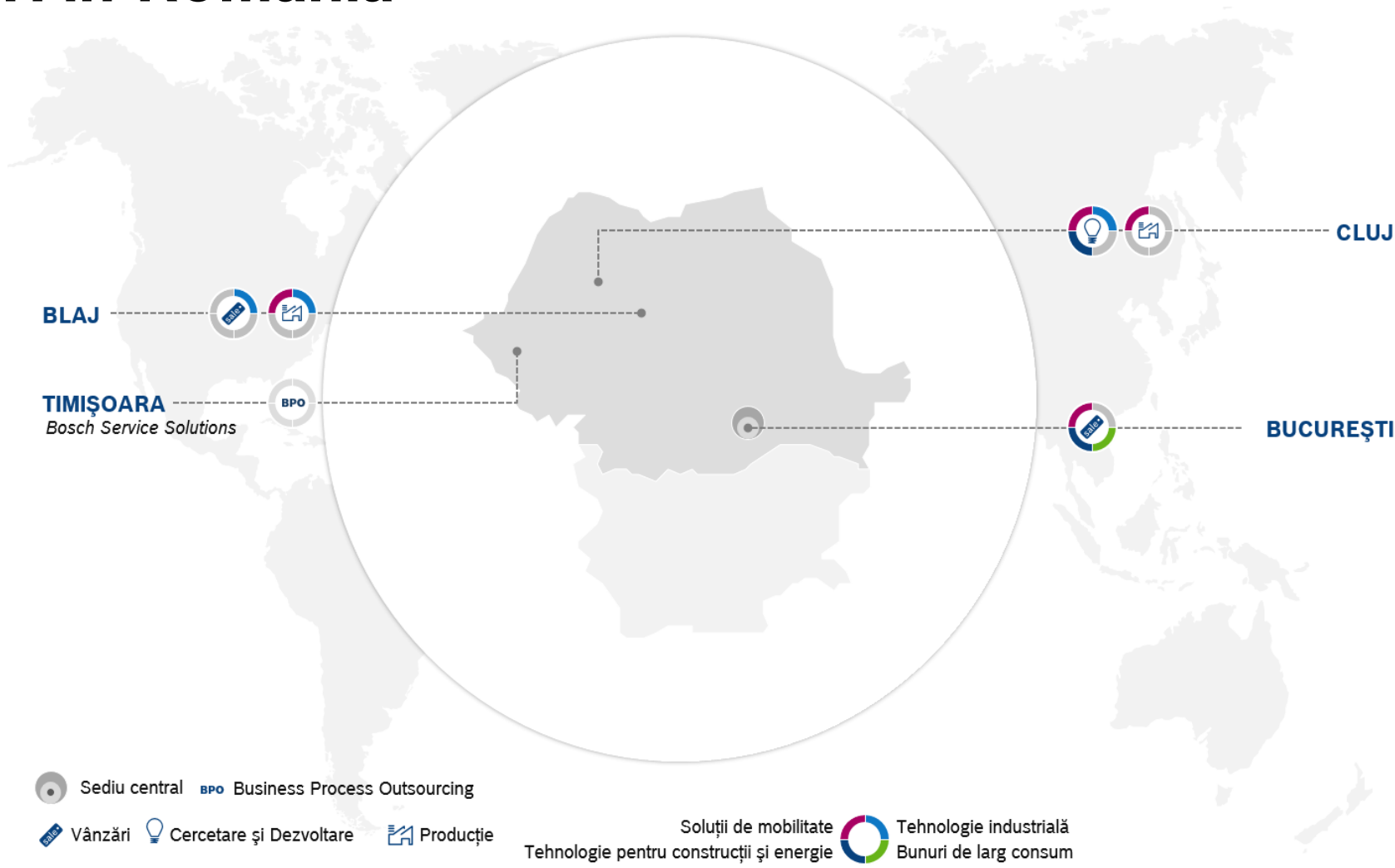
**Energy and  
Building  
Technology**



**Consumer Goods**



# BOSCH in Romania

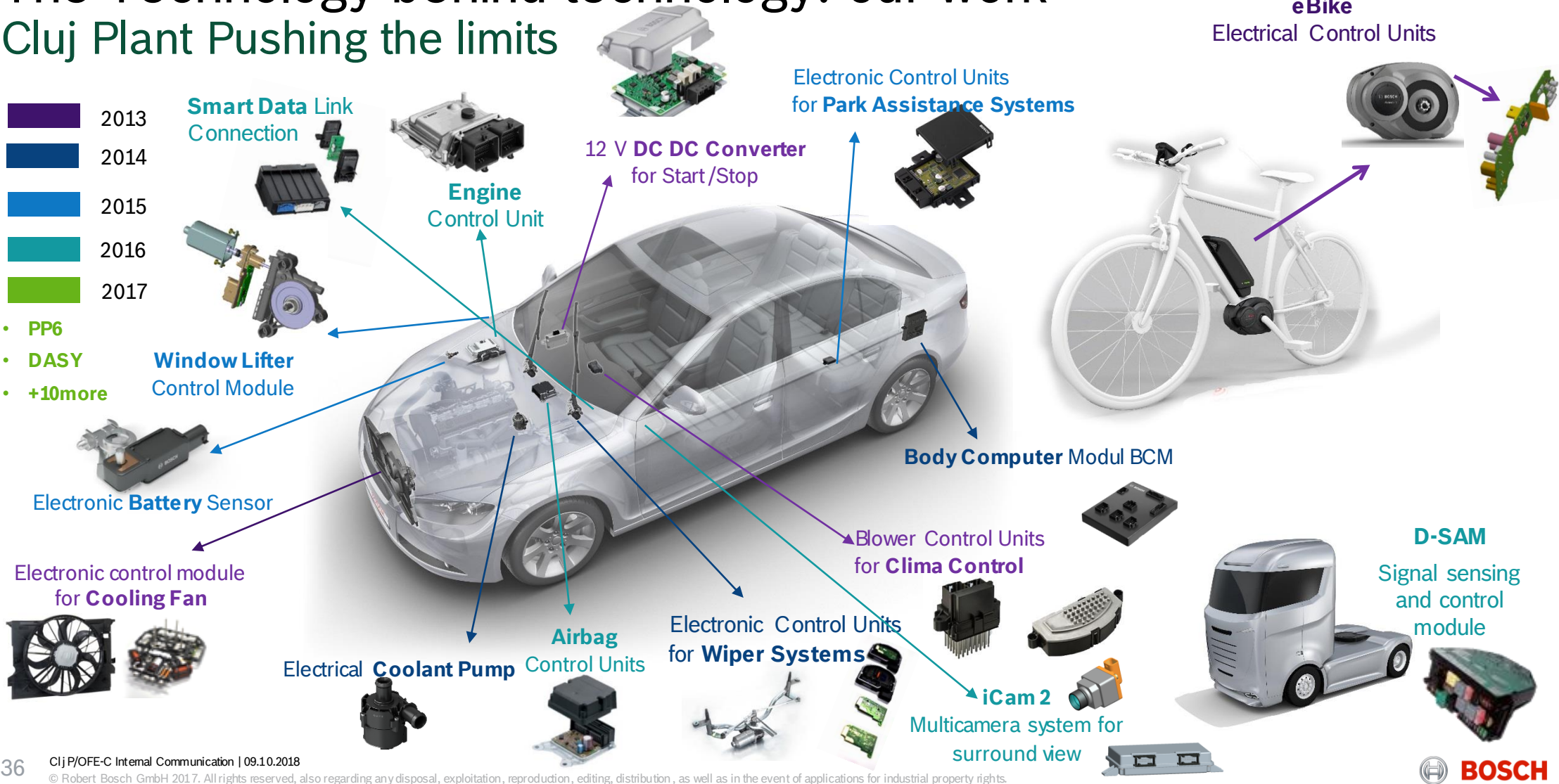


# The Technology behind technology: our work

## Cluj Plant Pushing the limits

- 2013
- 2014
- 2015
- 2016
- 2017

- PP6
- DASY
- +10more



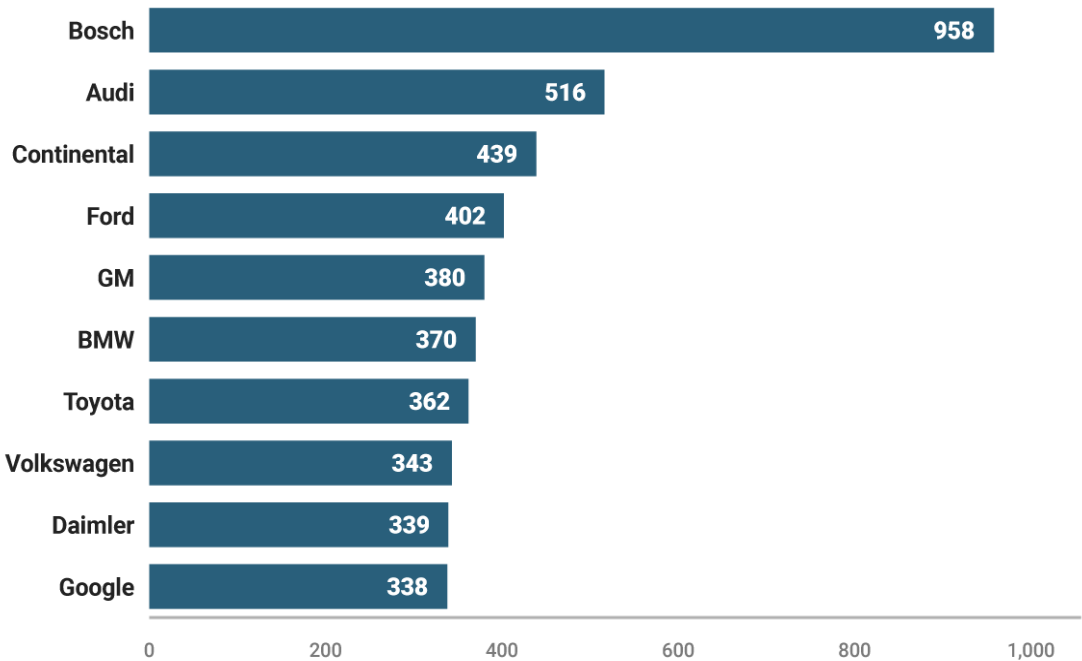
# Why Bosch?

## Leader in Autonomous Driving Patents

TECH CHART OF THE DAY

### WHO LEADS THE AUTONOMOUS DRIVING PATENT RACE?

Number of worldwide patent filings related to autonomous driving (January 2010–July 2017)



SOURCE: Cologne Institute for Economic Research, WIPO

statista | BUSINESS INSIDER

# THANK YOU FOR YOUR ATTENTION!