GTC 2017

AUTOMATED TRUCK DRIVING AND PLATOONING WITH DRIVE PX 2

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Motivation
Truck related efficiency topics (focus EU)

Energy Efficiency

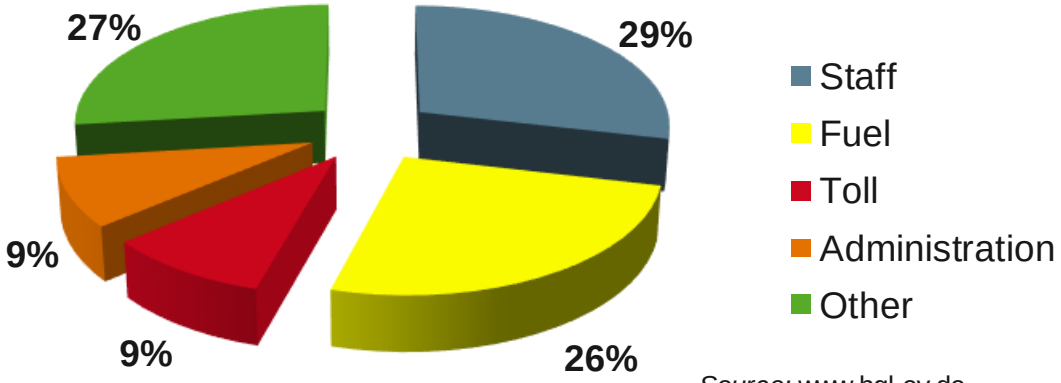
Source: dieterblasl

Traffic Efficiency

Source: t-online.de

Cost Efficiency

Average Portions of Costs in 2013 (Germany)



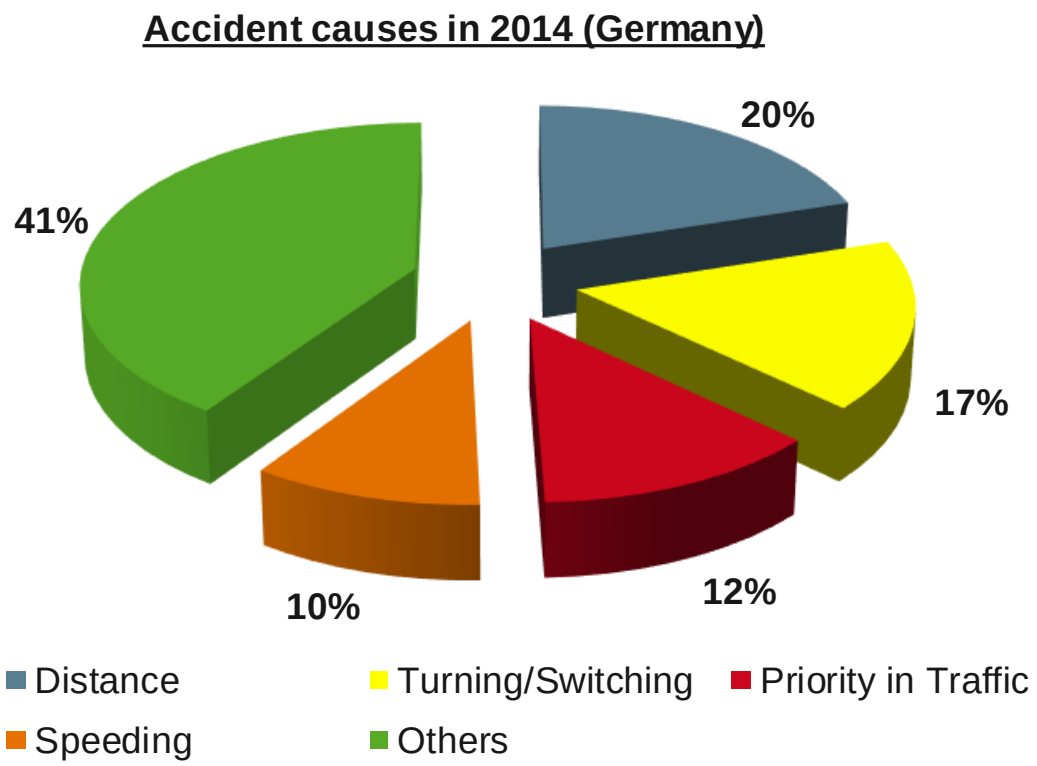
Source: www.bgl-ev.de

Staff Efficiency

Source: stuttgarter-zeitung.de

Motivation
Truck related safety topics

Source: remseck.freiewaehler.de



→ Too small gaps are the main reason for truck accidents in Germany!

Basic truck ADAS information

Today‘s available truck DAS

ACC

Source: DAF

PPC

Source: Mercedes Benz

AEB

Source: DAF

LDW

Source: trucknews.com

→ Introduction of new truck Advanced Driver Assistance Systems (ADAS) only if mandatory or a clear business case for fleet owners available!

Motivation
Truck related driving pleasure topics

Source: express.de

„Robot & Us: Self-Driving Trucks Are Coming to Save Lives and Kill Jobs"
Source: Wired, 05th May 2017

Source: lasiportal.de

Technology transfer passenger vehicle to truck

Examples for challenges

Dimension Variations

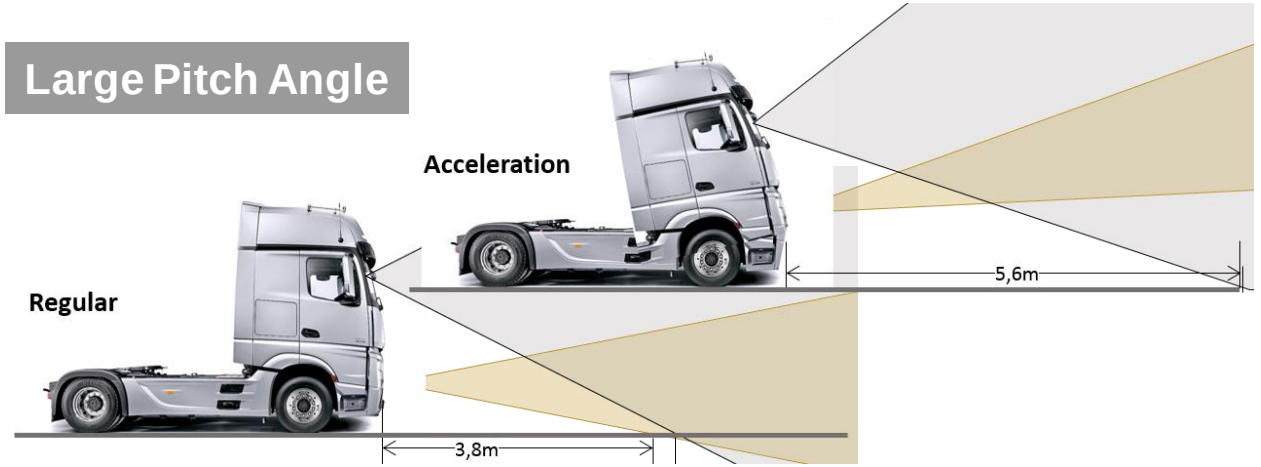
Source:mercedes-benz.co.uk

Configuration Variations

Source:fahrzeugbilkder.de

Source:beschriftungscenter-fuechsl.de

Large Pitch Angle



Connectivity & automation

Levels of automation and levels of connectivity

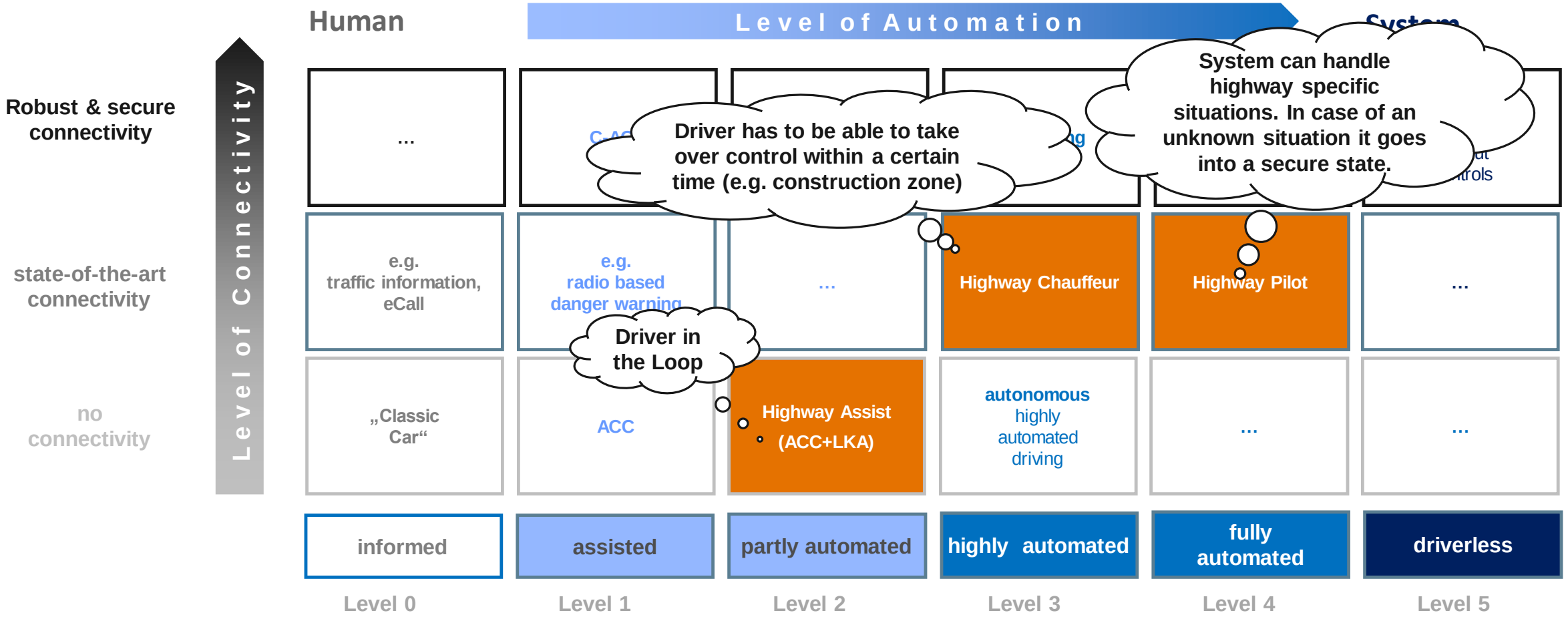
Human → Level of Automation → System

Level of Connectivity

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
	informed	assisted	partly automated	highly automated	fully automated	driverless
Robust & secure connectivity	...	C-ACC	...	Platooning	Platooning	Google Car without controls
state-of-the-art connectivity	e.g. traffic information, eCall	e.g. radio based danger warning	...	Highway Chauffeur	Highway Pilot	...
no connectivity	„Classic Car“	ACC	Highway Assist (ACC+LKA)	autonomous highly automated driving	...	...

Connectivity & automation

Levels of automation and levels of connectivity



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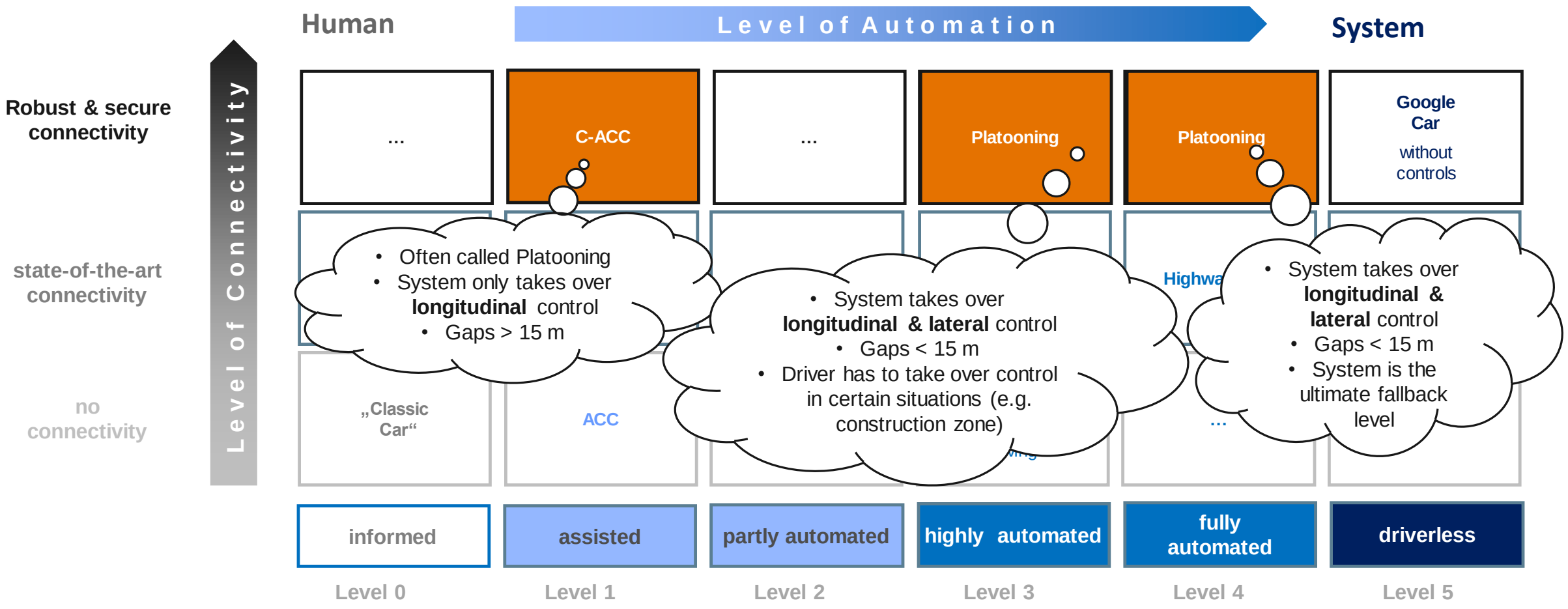
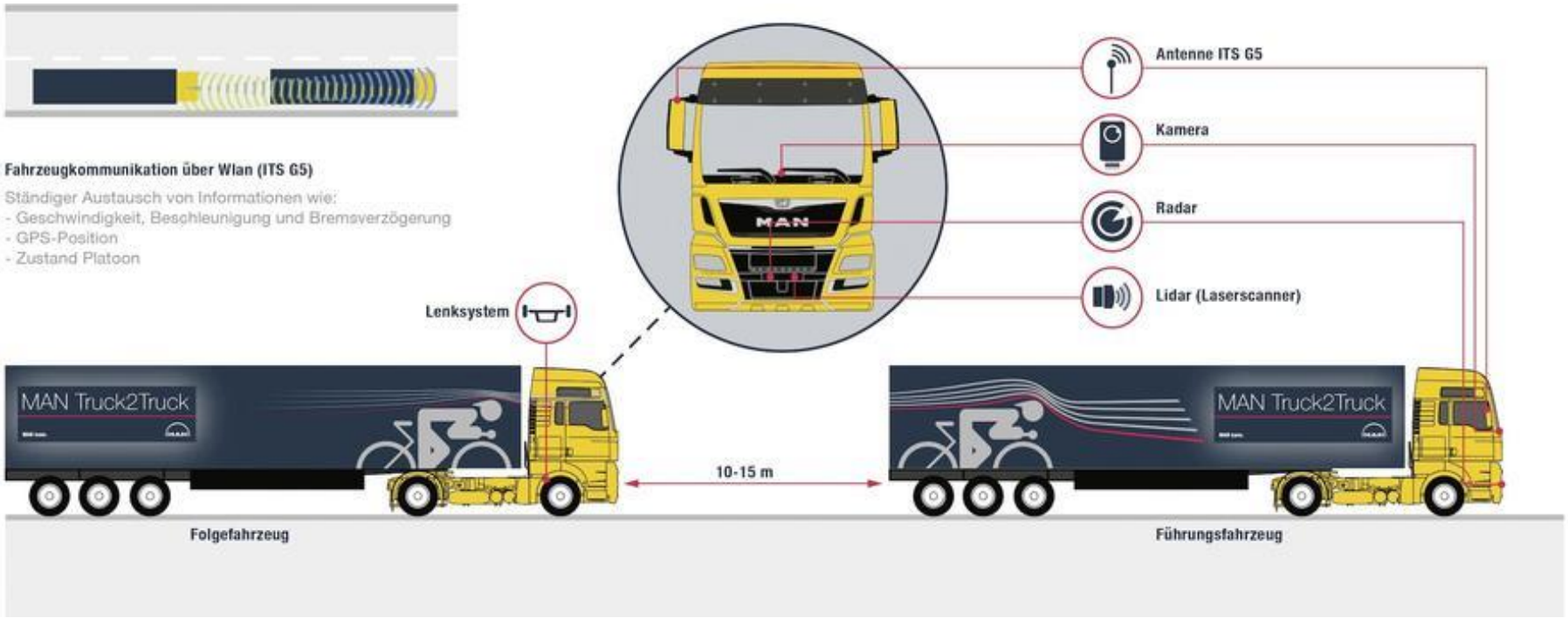


Platooning
Overview & goals of platooning system



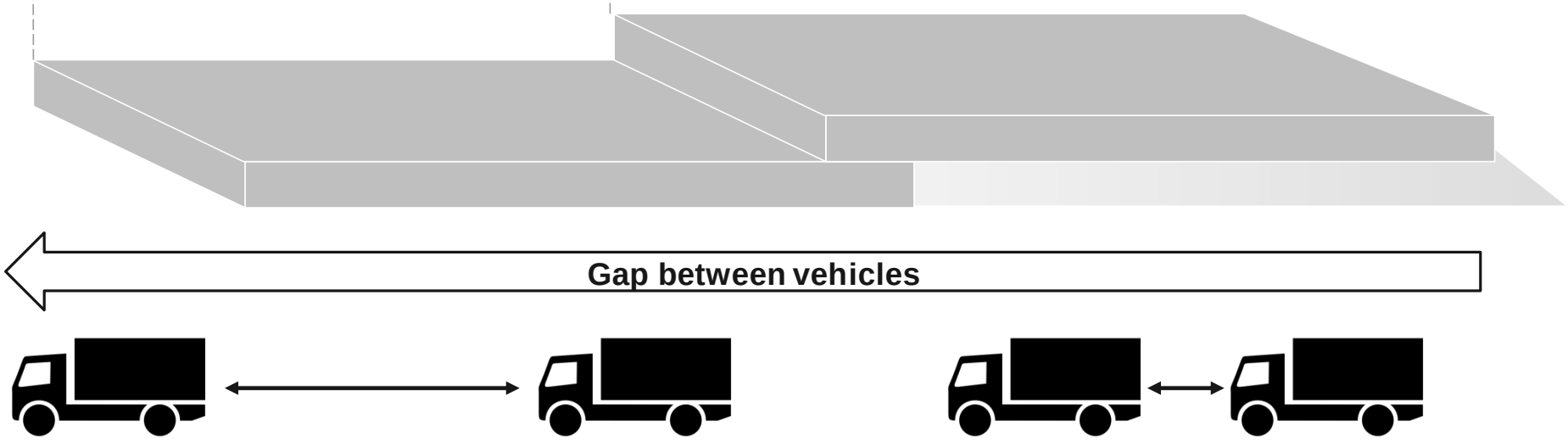
Source: man-truckers-world.de

Goals

- Improvement of **safety** due to longitudinal and lateral guidance
- **Relieve and support** for professional drivers
- Improved **road space**
- Optimization of **traffic flow**
- Reduction of **fuel consumption** due to slipstream driving

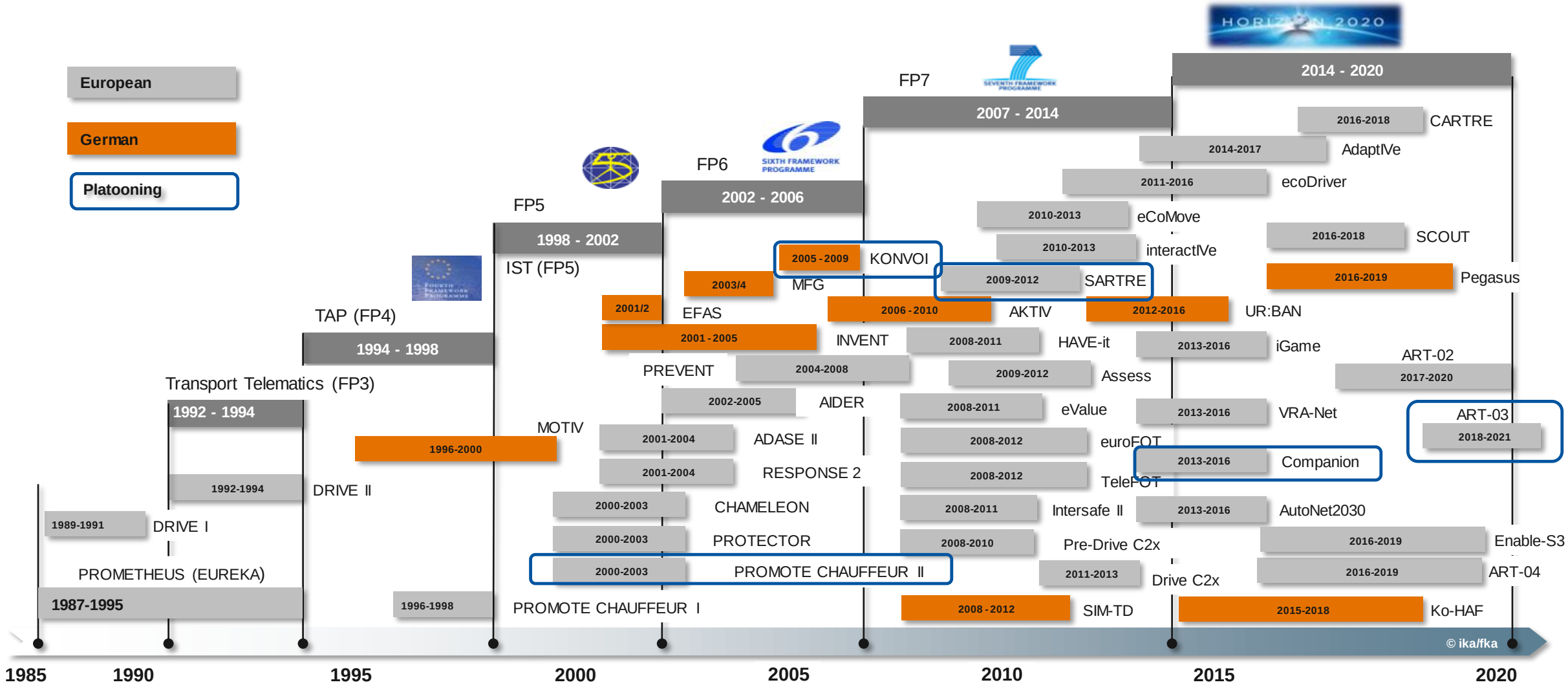
Platooning
Different types of platooning

Longitudinal Control	Lateral & Longitudinal Control
▪ Also called "*Cooperative ACC*" ▪ Driver in the following truck still has to steer ▪ Level 1 system	▪ Following trucks follow first truck automatically ▪ Following truck driver does not have to steer, brake or accelerate



Status quo on automated driving

A highly relevant research topic for many years



Platooning Projects
KONVOI

Goal

Practical usage of truck platoons in road freight transport for verification of prognosticated effects (economy of road space, reduction of fuel consumption, …)

Project overview

- Duration: 2005 – 2009
- Funded by the German Federal Ministry for Economic Affairs and Energy
- Project Partner: RWTH Aachen University, BAST, MAN, WABCO

Platooning Projects
KONVOI

Functionality of the system

- Electronic coupling of **two or more trucks**.
- Target distance between vehicles is **10 meters**.
- The KONVOI-system includes **lateral and longitudinal guidance**.
- The leading vehicle will be driven manually.
- The following vehicle will be automatically driven in longitudinal and lateral direction.
- The system is monitored by a truck driver at all times.
- The KONVOI-System can be overruled by the driver at any time.

Platooning Projects
KONVOI

Overview test truck equipment

- GNSS position determination
- Vehicle-to-vehicle communication
- Image processing
- In-Car PCs & microcontroller
- Steering torque and angle interface
- Distance sensors
- dSpace AutoBox
- Digital map
- Brake booster

Platooning Projects
KONVOI

Test runs on public highways in 2009

→ First operation of platoons in real traffic worldwide!

Platooning Projects
European Platooning Challenge 2016

Automated Driving
From Sensing to Trajectory Planning

Automated Driving can typically be divided into

- 1. Perception: Digitalization of environment – object detection, freespace detection, characterization
- 2. Localization: Mapping of objects into local coordinate system
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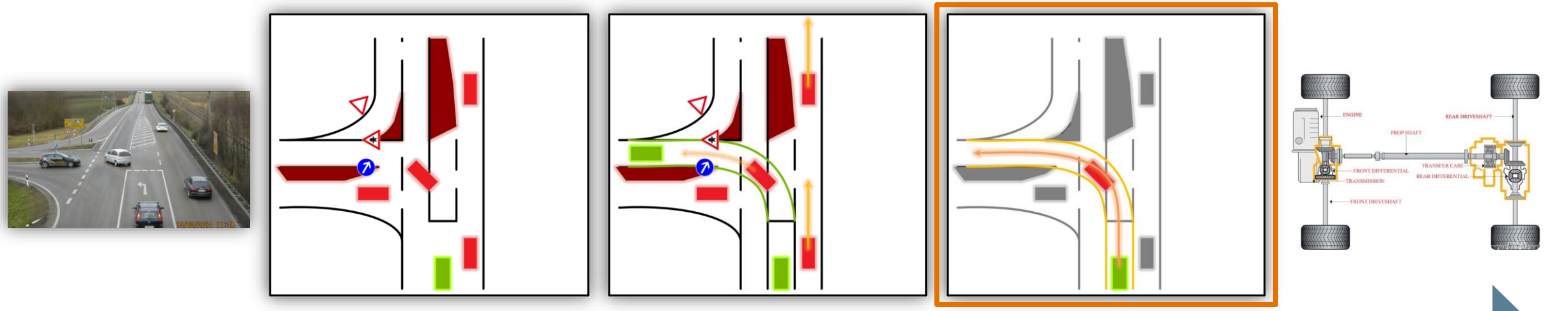


Sensing → **Perception & Localization** → **Behavior Generation** → **Trajectory Planning** → **Actuation**

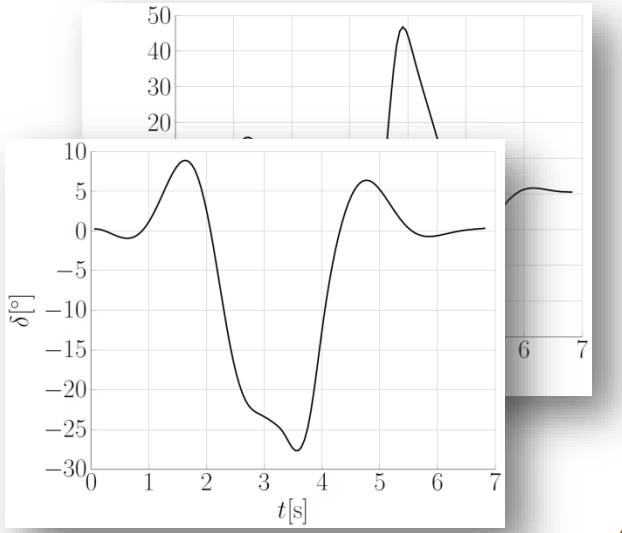
Motion Planning for Assisted and Highly Automated Cars/Trucks

Trajectory Planning

Simplification of the trajectory planning problem

- Find a suitable **control function**, i.e. a steering and speed profile, which
  - guides the vehicle in a **safe** and **comfortable** manner through the environment
  - **respecting** vehicle's and environmental **constraints**, e.g. max steering angle, collision avoidance, vehicle tilting limit, road friction

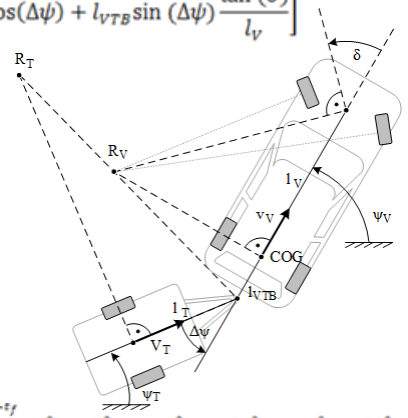
Control Function



Vehicle Model & Rating

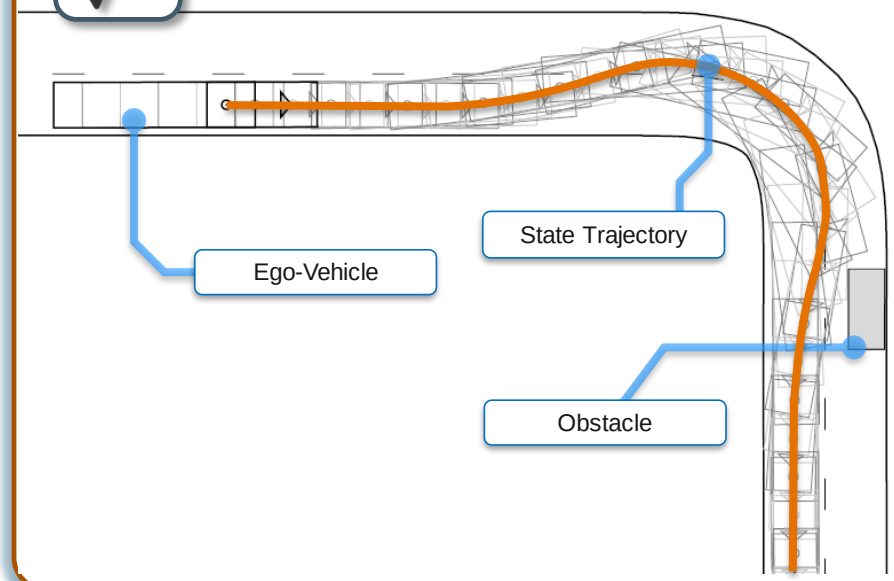
$$\dot{\psi}_V = \frac{v_V}{l_T}\left[\sin(\Delta\psi) - l_{VTB}\cos(\Delta\psi)\frac{\tan(\delta)}{l_V}\right]$$

$$v_T := v_V\left[\cos(\Delta\psi) + l_{VTB}\sin(\Delta\psi)\frac{\tan(\delta)}{l_V}\right]$$



$$J = \int_{t_0}^{t_f} \alpha_\kappa \dot{\kappa}^2 + \alpha_{\dot{\kappa}} \ddot{\kappa}^2 + \alpha_{\dot{\psi}} \Delta\dot{\psi}^2 + \alpha_{\Delta q} \Delta q^2 + \alpha_v \Delta v^2 + \alpha_{\dot{v}} \Delta\dot{v}^2 + \alpha_j \dot{v}^2 dt$$

Drivable Trajectory



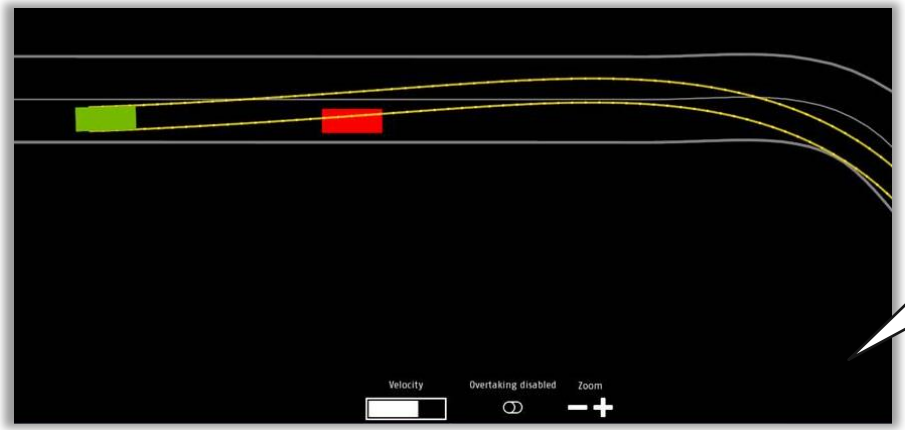
Cooperation Between NVIDIA and fka

History and Future Plans

History

- First contacts in late 2014
  - Loose conversations and meeting in Santa Clara, CA
- fka presented its motion planner @ELIV 2015, Baden Baden
  - Contact to NVIDIA
- Further exchange on phone, physical meeting @fka
- fka and Nvidia become partners, fka gets full access to Drive PX
- fka is invited to join NVIDIA at its booth @CES 2016

fka's Motion Planner @CES 2016, at the NVIDIA booth



Demo of fka's Motion Planner

Future plans

- Widen partnership in industrial projects
  - Possibly integrate motion planner to DriveWorks software stack

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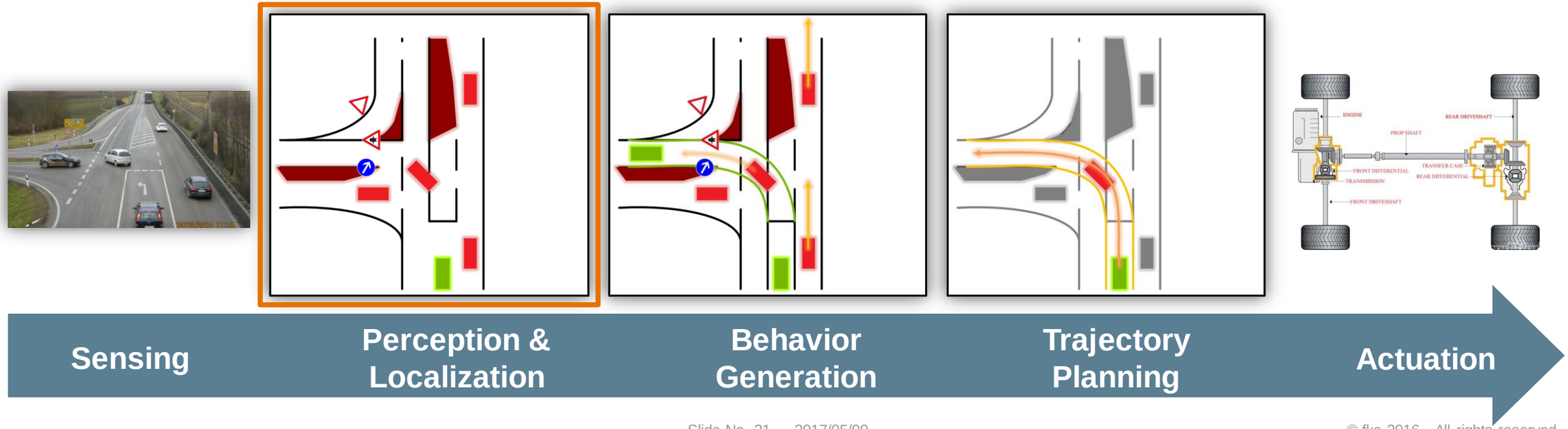


Neural nets for lane marking recognition (based on AlexNet)

Comparison of three different nets

Complex

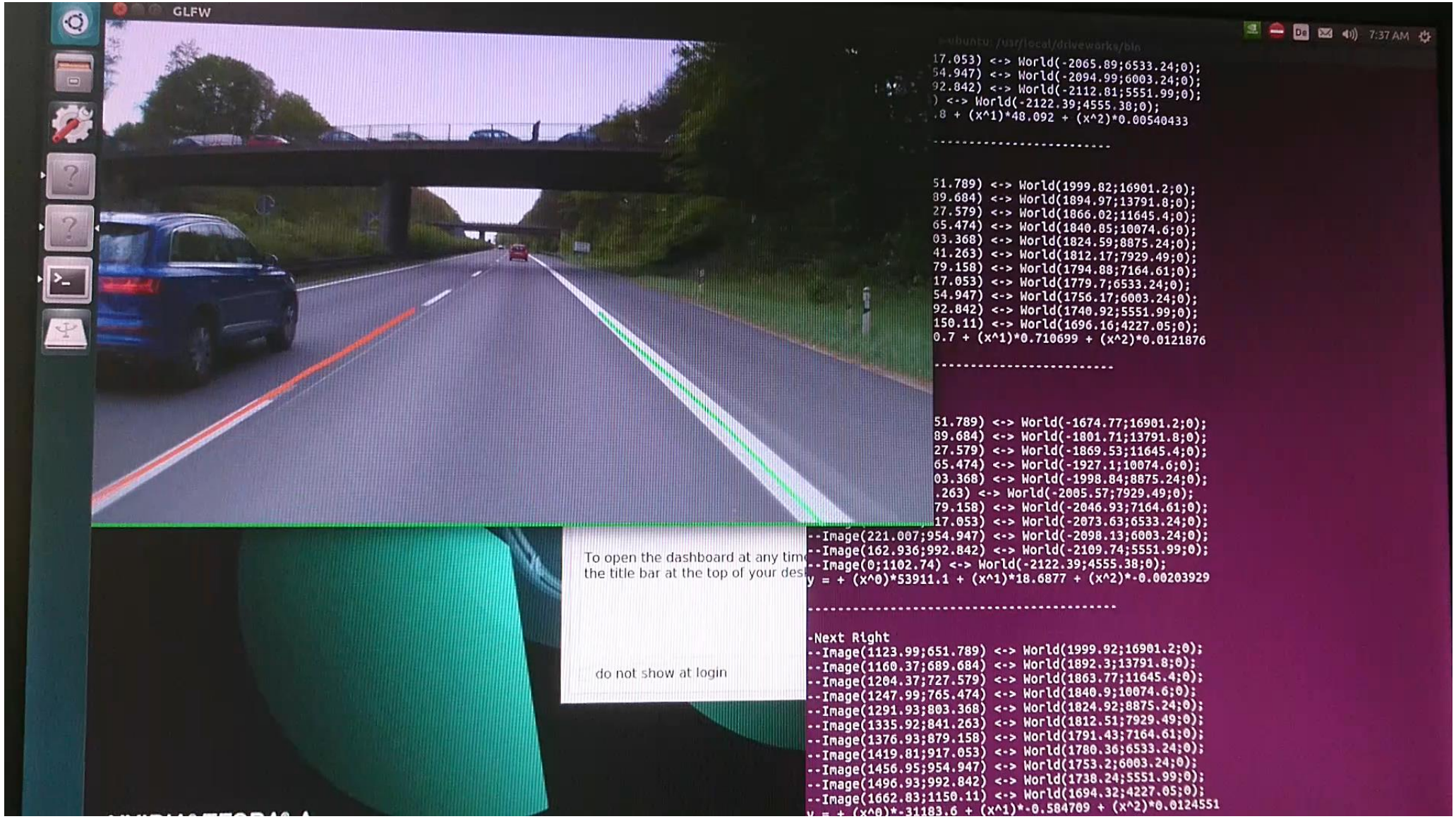
Normal

Thin

→ All nets very computational expensive and not executable in real-time on Drive PX 2
→ Using NVIDIA's LaneNet on Drive PX 2

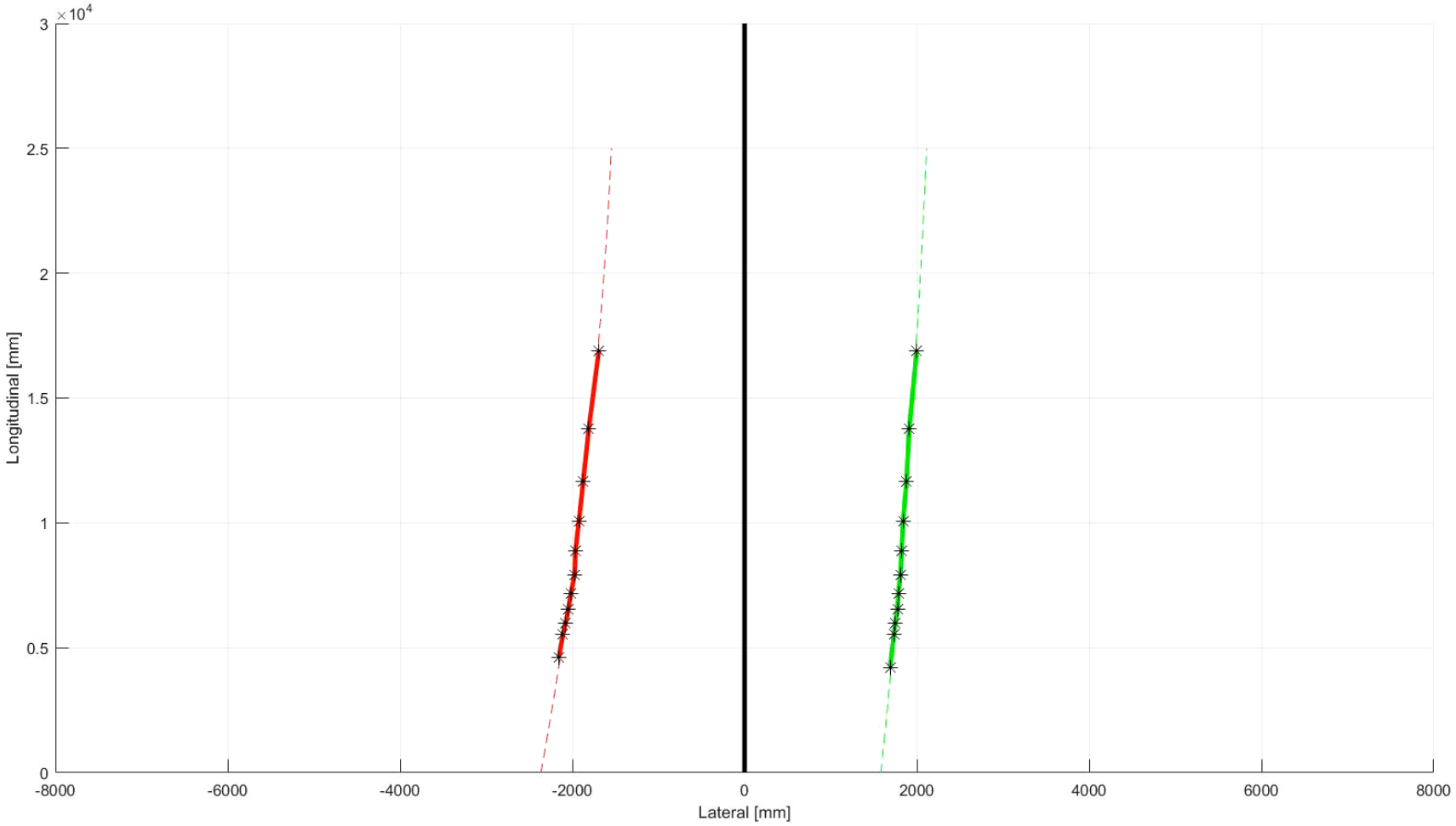
NVIDIA LaneNet

Running on Drive PX 2 with parameter extraction



Control parameter derived from LaneNet

Control input for lane following control



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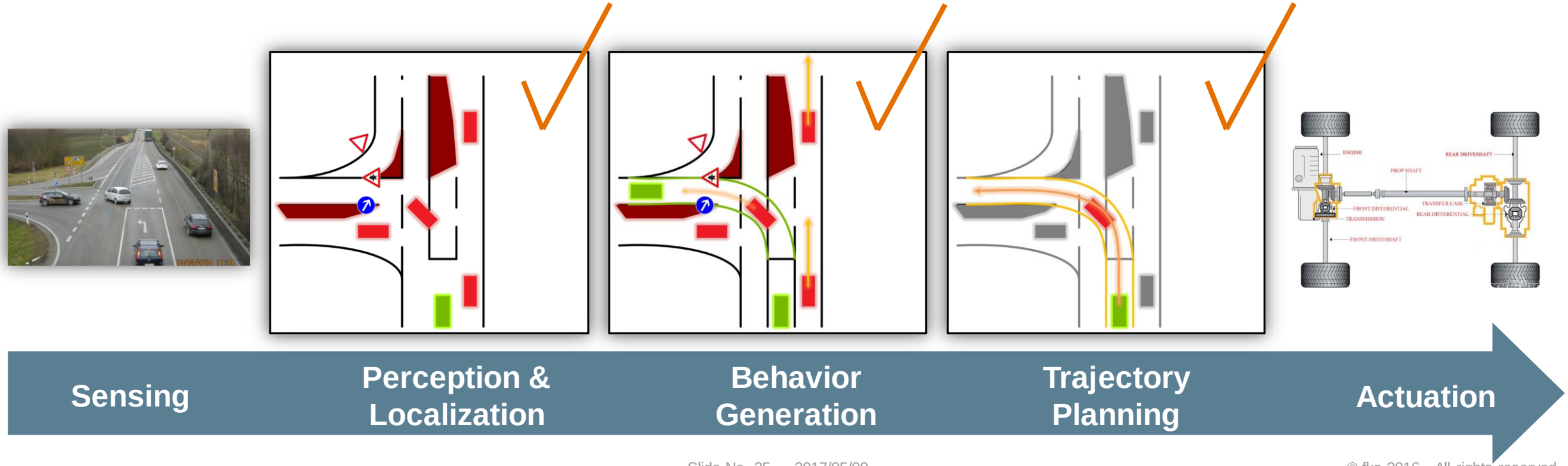

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