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Autonomously Driving Trucks

Challenges and Opportunities

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About Presenter and Talk

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Presentation:

- Background: Autonomous trucks and Advanced Driver Assistance Systems (ADAS).
- Specific challenges for autonomous technology for trucks.
- Outlook on future for autonomous trucks.

About Knorr-Bremse

- Leading provider of braking systems for trucks buses, trailers, agricultural machines.
- Also world leader in provider of equipment for rail vehicle systems.
- Decades of expertise in developing braking systems:
  - pneumatics, mechanics, electronics, control engineering.
- Now applying of domain expertise for developing autonomous driving systems for trucks.

Autonomous Trucks – Why?

- Improved safety: reducing the number of accidents.
- Improved efficiency: optimized driving, more driving hours.
- Coping with increasing shortage of truck drivers now and in future.

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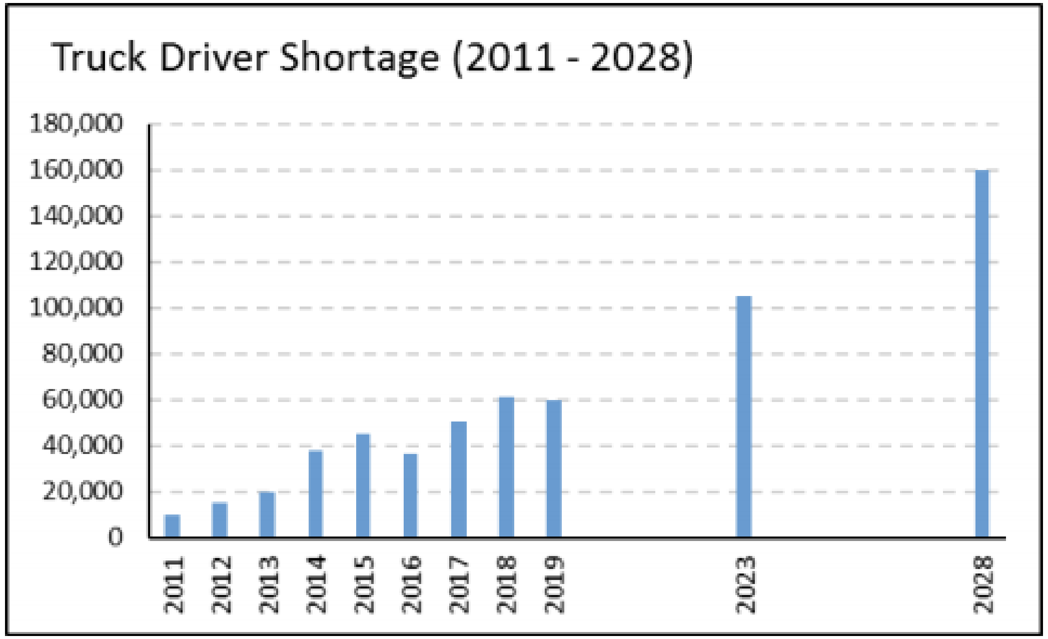
Trucks / Lorries: Case for Autonomous Operation

- Shortage of truck drivers:
  - Additional 45.000 truck drivers currently needed in Germany [1].
  - In US 2028: shortage of 160,000 truck drivers [2].
- Efficiency gains in logistics:
  - US anticipates 55% TCO savings in 2027 with fully autonomous trucks [3].



Source: "Truck Driver Shortage Analysis 2019," ATA

[1] A.Kulikowska-Wielgus, Trans.info, 2018, https://bit.ly/3b12iHH

[2] S.Seltz-Axmacher, 22 Apr 2020. The Poor ROI of Autonomy. https://bit.ly/3c1tFm7

[3] McKinsey, 2018. Distraction or disruption? Autonomous trucks gain ground in US logistics. https://mck.co/2ygHdeU

Trucks / Lorries on Public Roads

- In 2016 in Europe [1]:
  - 55.9M commercial vehicles, of those 12.6M trucks/lorries. 326.8M passenger cars.
- Fatalities [2]:
  - 5% of total in 2016.
  - Decrease from 1161 in 2007 to 674 in 2016.

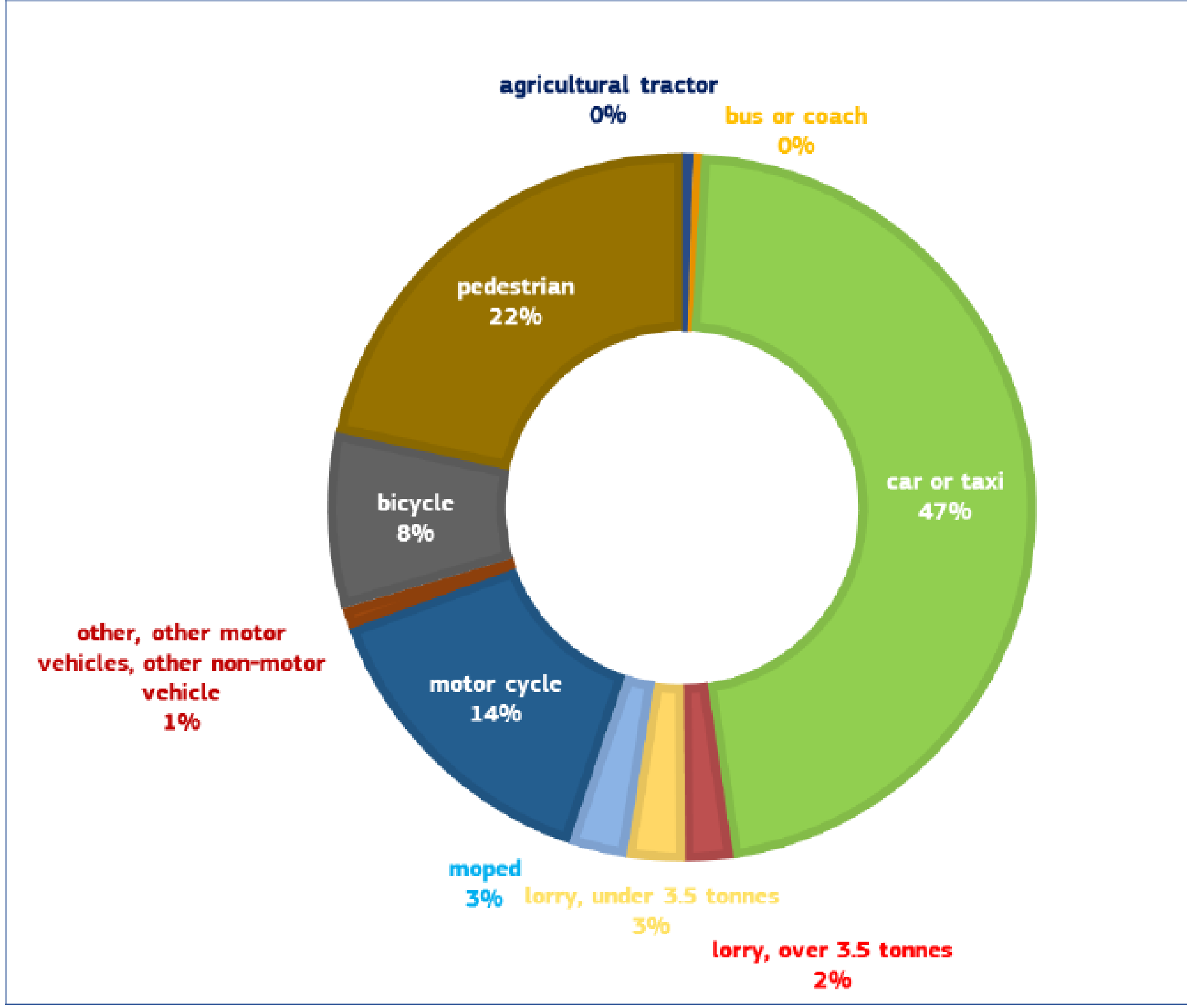
[1] European Automobile Manufacturers Association (ACEA), 2018, https://bit.ly/3fhBI0b

[2] European Road Safety Observatory (ERSO), 2018, https://bit.ly/2WpKmkE

Accident involving Trucks / Lorries on Public Roads

- In EU: Number of fatalities in truck accidents: 2% [1].
- In US: #of deaths in truck accident increase, while #of deaths in all other motor vehicle crashes are declining [2].

Figure 14: Distribution of fatalities by mode of transport in the EU, 2016



Source: CARE (EU road accidents database) or national publications
Last update: April 2018

[1] European Road Safety Observatory (ERSO), 2018, https://bit.ly/2VZLFrq

[2] Jerry Hirsch, Trucking Fatalities Reach Highest Level in 30 years. 22 oct 2019, trucks. https://bit.ly/2Wqb1hq

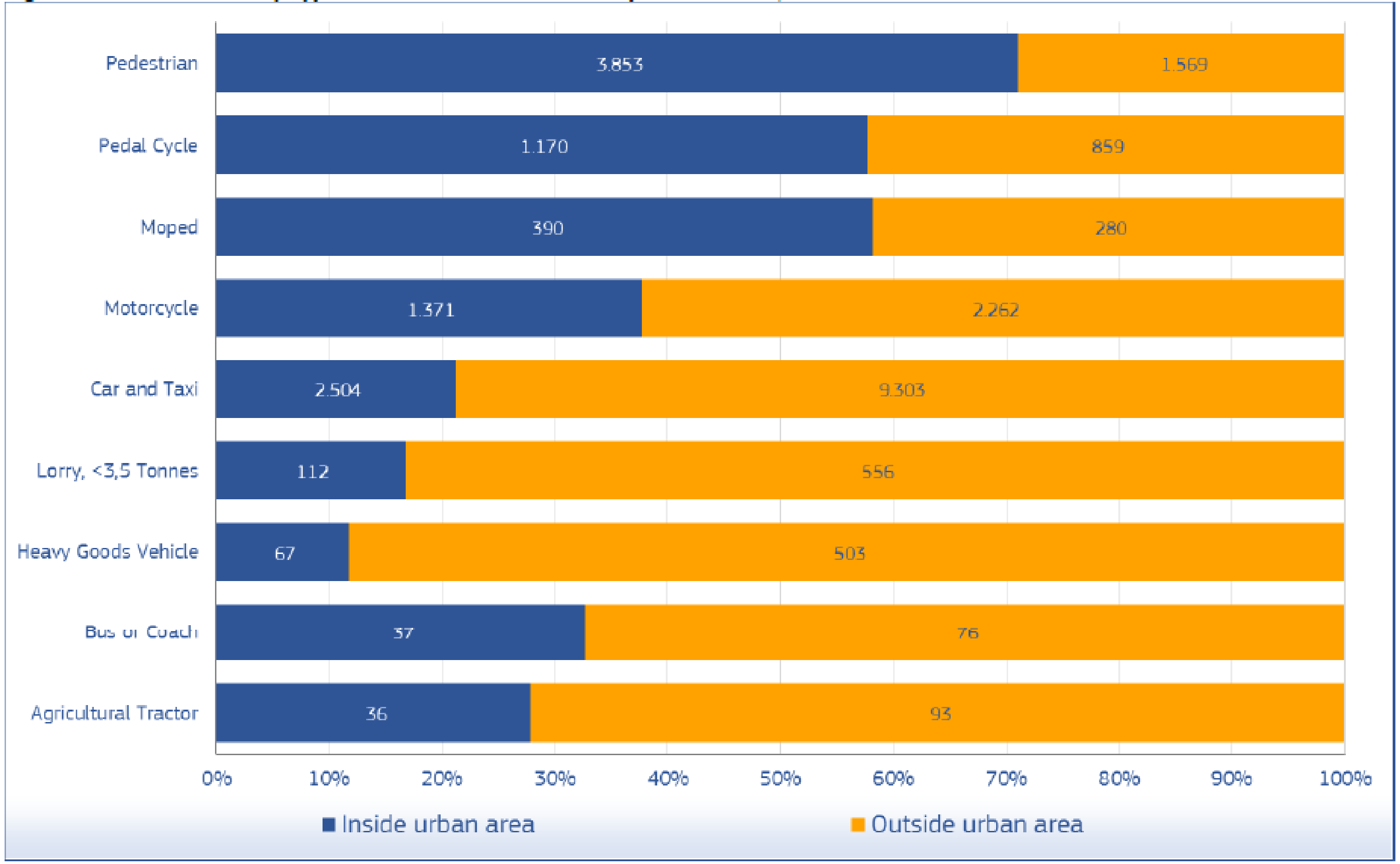
Trucks / Lorries Accidents

- Most fatalities of truck accidents outside urban areas [1].
- 50% of truck accidents (2015): collision at end of standing traffic [2].

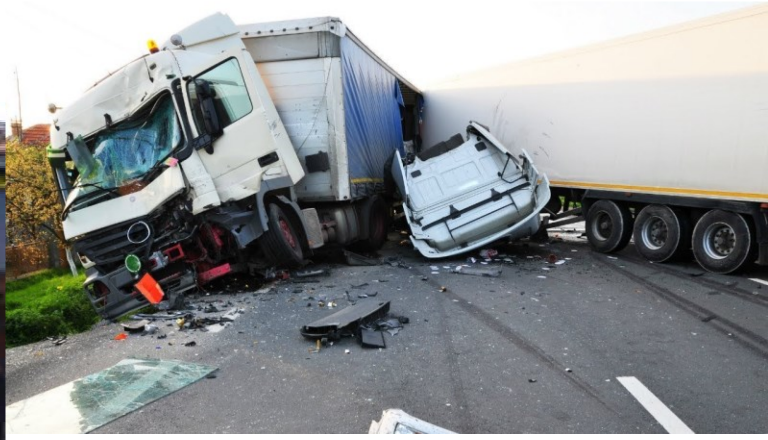
[1] Fig. 20: European Road Safety Observatory (ERSO), 2018, https://bit.ly/2Wghrj4

[2] DVR 2016, Notbrems-Assistenzsysteme für Nutzkraftwagen, https://bit.ly/2VT4RqO

Figure 20: Fatalities by type of area and mode of transport in the EU, 2016



Source: CARE (EU road accidents database) or national publications
Last update: April 2018



Accidents with trucks

Legal ADAS Requirements for New Trucks in Europe

- Lane Departure Warning System (LDWS) since Nov 2009
- Advanced Emergency Brake System (AEBS):
  - Level 1: speed reduction to 30 km/h (moving obstacle) resp 70 km/h (standing obstacle).
  - Level 2 (since Nov 2018): speed reduction down to 10 km/h (moving obstacle) resp 60 km/h (standing obstacle).
  - Since Nov 2018 minimum reduction of speed by 20 km/h (vehicles > 8t).
  - Potential of ideal AEBS: avoidance of 25% of accidents, 45% of deaths [1]
- Detailed specifications by UN in Feb.2019 [2]:
  - E.g. warning to driver 0.8 sec before automatic emergency braking.

- Consequence:
  - Number of fatalities in truck accidents decreased from 1161 (2007) to 674 (2016) [3].

[1] DVR, Notbrems-Assistenzsysteme für Nutzkraftwagen, 2016, https://bit.ly/2YsNz5P

[2] UN, 12 Feb 2019, http://www.unece.org/?id=51189

[3] European Road Safety Observatory (ERSO), 2018, https://bit.ly/2WpKmkE

SAE Levels of Driving Automation

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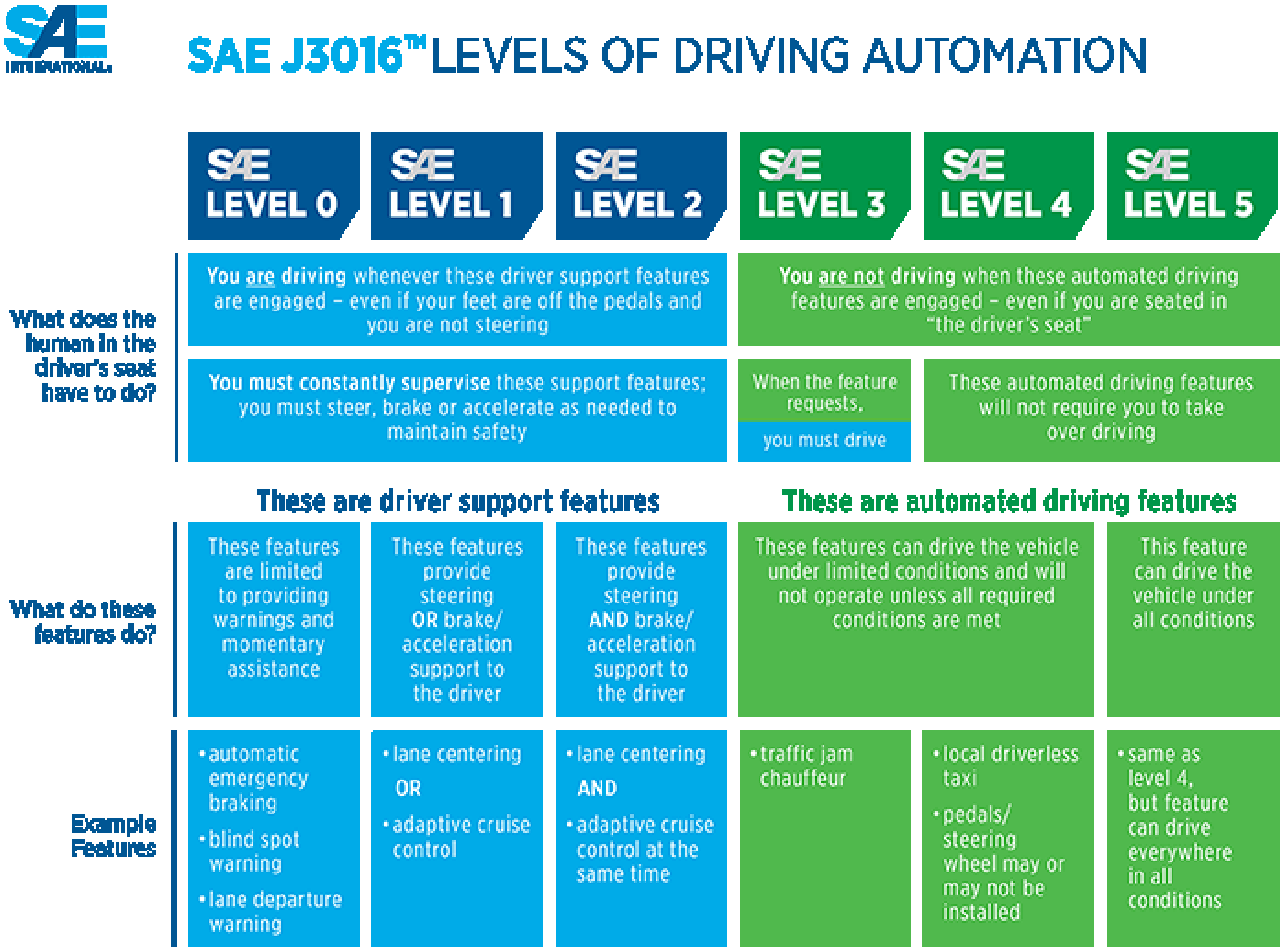
Graphical representation of the SAE levels of autonomous driving, revised by SAE in 2018.



SAE J3016 Levels of Driving Automation, 2018, https://bit.ly/2VUsdN0

Legal Requirements for Autonomous Vehicles

- Worldwide many publications by government agencies and insurers regarding autonomous vehicles.
- These are guidelines and requirements for
  - Minimum capability,
  - Takeover and handover times and processes.

[1] NHTSA, Human Factors Design Guidance for Level 2 and Level 3 Automated Driving Concepts, Aug 2018. https://bit.ly/2SwuPyk

[2] ABI / Thatcham, Defining Safe Automated Driving, Aug 2019. https://bit.ly/3c2xlI4

History of Autonomous Trucks

2004: US DARPA Grand Challenge, “Team TerraMax”, truck by Oshkosh.

2005: Komatsu, autonomous mining vehicles [1].

2013-2017: US Army: Autonomous Mobility Applique System (AMAS) [2].

2016-2020: Starsky Robotics. First street legal fully-unmanned truck. “*Supervised machine learning doesn’t live up to the hype.*” Main concern: “*safety not appreciated by investors*”.

2016: OTTO founded by A.Levandowski. Development of hardware kits for long-haul trucks. Was acquired by Uber, shut down in 2018.

2019: first coast-to-coast commercial Level-4 system, by Plus.ai [4].

[1] Komatsu, Autonomous Haulage System, https://bit.ly/2YoXokZ

[2] Lockheed Martin, 2017, AMAS https://lmt.co/2SrfZJy

[3] Stefan Seltz-Axmacher, The End of Starsky Robotics, 19 Mar 2020, Medium, https://bit.ly/3d26icc

[4] A.Frost, Autonomous truck completes USA’s first commercial freight run across the country. TTT, 12 nov 2019, https://bit.ly/2YyZC1k

Currently Available Truck ADAS Technology

- Most current commercially available ADAS technology (including for trucks) is SAE-Level 2.
- Latest development efforts are targeted towards of SAE-Level 3+.

- BUT:
  - There is concern that SAE-Level 3 is unrealistic, requiring human drivers to be fully attentive while system drives “mostly” autonomously [1].
  - Takeover time (from system to driver) is recommended to be 5-7 seconds [2].
  - But full situational awareness of driver takes longer (>45 sec) [3].

- Therefore:
  - More focus on development of SAE-Level 4 autonomy.

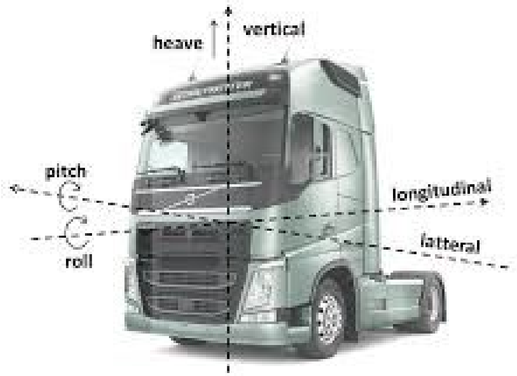
[1] P.Bigelow, Why Level 3 automated technology has failed to take hold. Automotive News, 21 jul 2019. https://bit.ly/2Wov53t

[2] NHTSA, Human Factor Design Guidance for Level 2 and Level 3 Automated Driving Concepts. NHTSA 2018. https://bit.ly/2VYFBQj

[3] Merat et al., Transition to manual: Driver behaviour when resuming control from a highly automated vehicle. TRP-F, v27, Part B, Nov 2014, pp274-82. https://bit.ly/2VYK4Cz

Transitioning ADAS Technology from Cars to Trucks

- Simpler than cars:
  - Trucks have lower speed. Size and weight provide “stability”.
- More difficult than cars:
  - Different overall system behaviour of trucks:
    - Weight (e.g. 40 tons): low acceleration and deceleration.
    - Size (trailers and semi-trailers), more complex kinematics.
    - Length of trucks and semi-trailers. More difficult to manoeuvre.
  - Sensors mounted on truck driver cabin need to compensate for cabin motion: has its own motion characteristics (dampening for driver comfort).
- Trucks more dangerous than cars:
  - Larger weight (momentum) causes more serious impact in collisions.
- Sensor systems must be adapted to mounting on trucks. AI approaches need to be trained to take into account truck characteristics.



From Ekberg & Hansson, 2015. https://bit.ly/2WkVqQ6

Truck Manufacturers with Autonomous Concepts

- Examples:
  - Volvo: Hub-to-Hub and SAE-Level 4 prototype.
  - Daimler (including Freightliner): aiming at SAE-Level 4.
  - Ford Otosan: Platooning in Turkey. Intent: SAE-Level 4.
  - MAN: networked platooning, self-driving trucks and safety vehicles (SAE-Level 4).
  - Scania: platooning, SAE-Level 4 (Scania AXL).
  - Iveco: driverless autonomous bus (SAE-Level 4).

Volvo

- Hub-to-Hub (2017): https://bit.ly/3dlnEBl
- Vera (2019): https://bit.ly/2L65ck5

Daimler (in US: Freightliner)

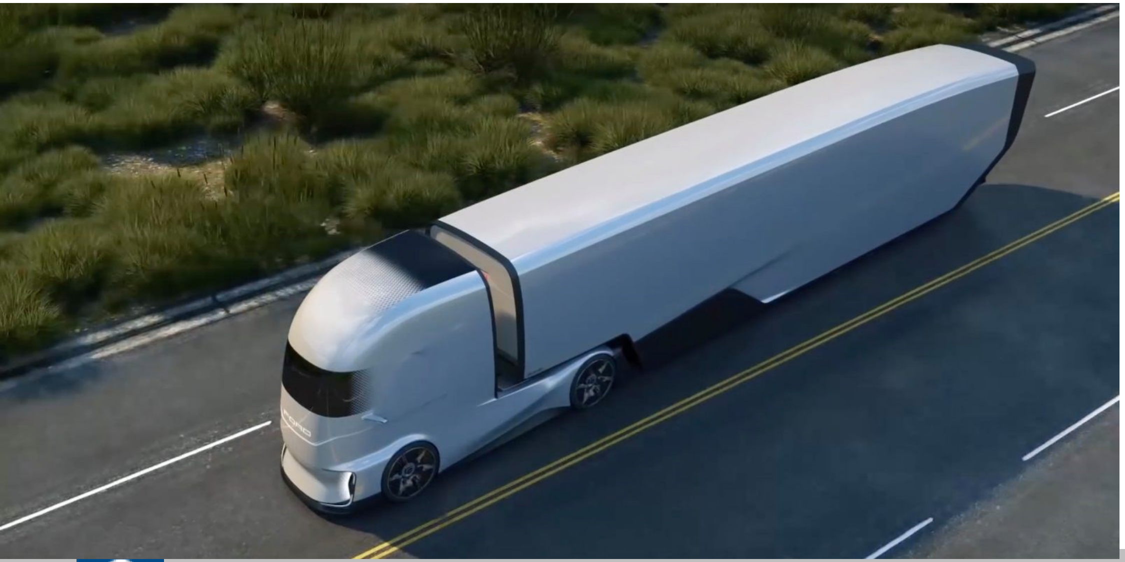
- Series production of SAE-Level 2 technology: Active Drive Assist, Active Lane Assist, in all speed ranges.
- Next aim: SAE-Level 4 [1].

Video: https://bit.ly/2KX0ODD

[1] Automated Driving at Daimler Trucks. https://bit.ly/3fdOL2F

Ford Otosan

- Turkish branch: Ford Otosan. Platooning. Electric truck. “F-Vision” truck concept.
- Collaboration with AVL. https://bit.ly/35sVscS https://www.youtube.com/watch?v=86hS5yGb6ZY

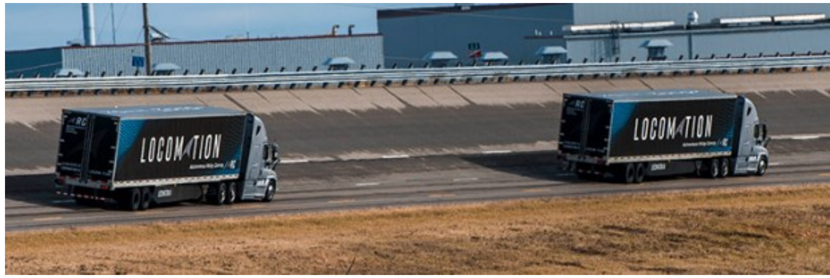


Scania

- SAE-Level 4 concept truck: Scania AXL. https://bit.ly/3d8Mmoc

Vehicle Technology Providers

- Peloton: platooning. https://peloton-tech.com/
- Locomation: platooning. https://locomation.ai/
- Aurora: fully autonomous system for trucks and cars (collaboration with Chrysler) https://aurora.tech/
- TuSimple: L4 autonomous shipments. https://www.tusimple.com/
- Plus.ai: https://plus.ai/
- Knorr-Bremse.
- Continental: sensors.



Autonomous Trucks in Asia

- Hutchinson Ports (Thailand) https://bit.ly/2WiSiEp
- Inception Technology (China) https://bit.ly/2xsGrLD

Autonomous Truck Concepts

- Concepts:
  - Hub-To-Hub Transport
  - Platooning
- Technologies:
  - Lane-Keeping
  - Distance-Keeping
  - Lane-Changing
  - On-Ramp / Off-Ramp for highways

Hub-to-Hub Autonomous Highway Transportation

- Autonomous driving between depots.
- Is seen as a new overall inclusive logistics solution.
- Is challenging, because not only highway, but also depots.
- Fully autonomous driving would be dock-to-dock.
- Depots need to be near highways.

Platooning

- Is basically an SAE-Level 1 system, but can have also higher-level functions.
- Leading vehicle can be driven by human driver.
- Following vehicles keep automatically a close distance to preceding vehicle.
- Envisioned advantages:
  - Better fuel economy (4% leader, 10% follower) [1].
- OEMs are working on follower technology.
  - Next generation: Follower is SAE-Level-4.

[1] R.Bishop, U.S. States are Allowing Automated Follower Truck Platooning while Swedes May Lead in Europe. Forbes, 2 May 2020, https://bit.ly/2WluH64

Collaboration Continental and Knorr-Bremse

- Continental
  - Sensor hardware (radar, lidar, camera).
  - Vehicle-to-vehicle communication.
- **KNORR-BREMSE**
  - Vehicle integration in truck demonstrators.
  - Driving systems, actuators.

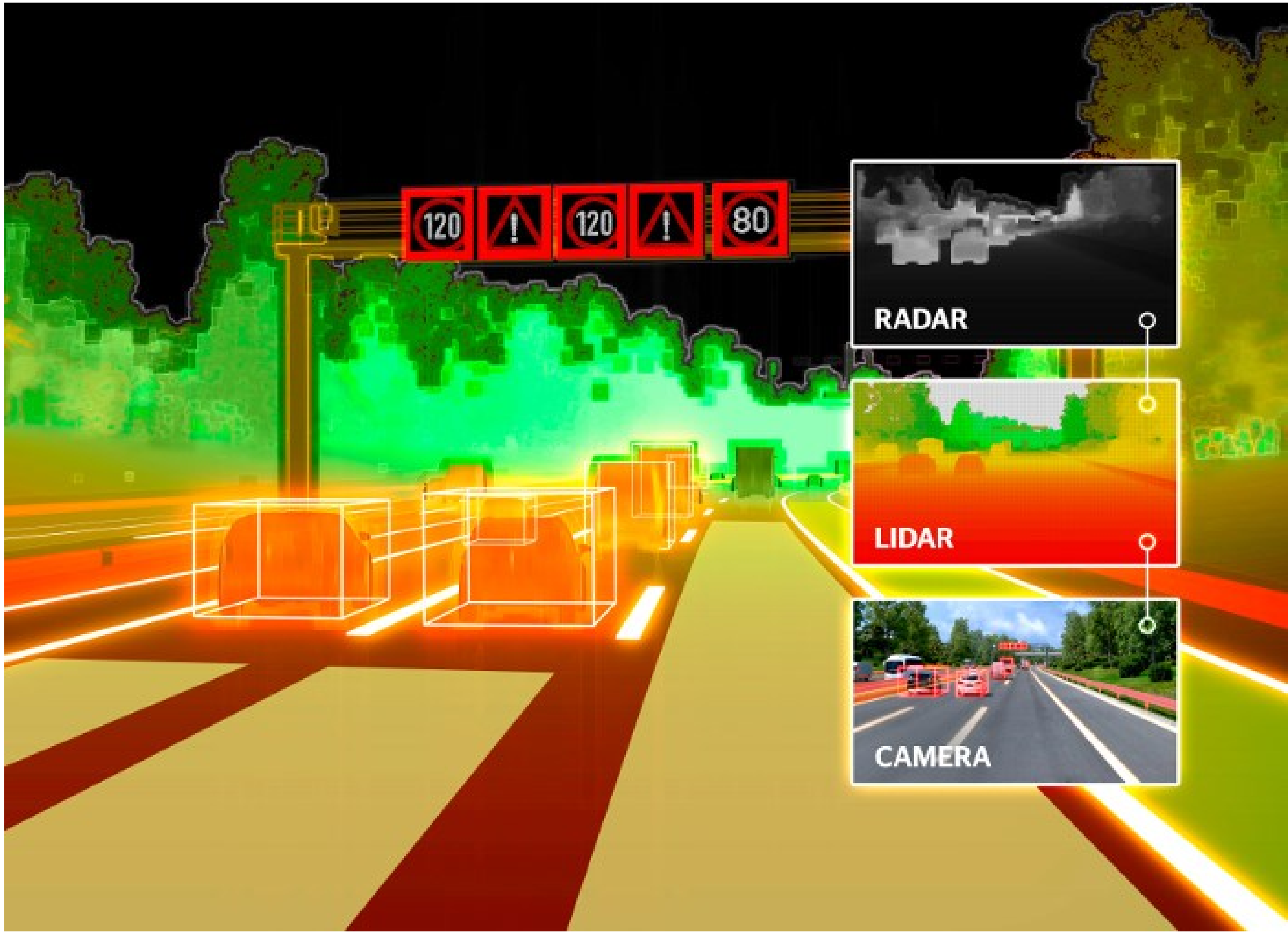


Image: Traffic Technology Today, 2019, https://bit.ly/2Yn4LJL

Knorr-Bremse / Continental Platooning Demonstrator

- Three trucks of different make.
- Demonstrated:
  - Platoon formation
  - In-sync driving
  - Auto emergency brake
  - Exit from convoy
  - Safe splitting of platoon
- Driver is present!

[1] Adam Frost, Continental and Knorr-Bremse complete truck Platooning Demonstrator project, 16 jul 2019, https://www.traffictechnologytoday.com/news/connected-vehicles-infrastructure/continental-and-knorr-bremse-complete-truck-platooning-demonstrator-project.html

KB & Conti Platooning

- https://www.youtube.com/watch?v=blnWUKWINak

KB Highway Pilot

- https://www.youtube.com/watch?v=Dx5OLJdYvBc

Certification of Safety

- Standards for safety:
  - Functional Safety in event of system failures: ISO 26262.
  - Safety of the Intended Functionality (Sotif): ISO/PAS 21448 standard. Covers safety in absence of faults. [1]
- In USA: NHTSA publishes company "Voluntary Safety Self-Assessments" (VSSA) [2].
- Investigations of how to demonstrate reliability of Autonomous Systems [3].

[1] R.Bellairs. Why SOTIF is Key for Safety in Autonomous Driving. Perforce. 24 Apr 2019. https://bit.ly/3fh0RIj

[2] NHTSA, Voluntary Safety Self-Assessment. https://bit.ly/2YoQoVs

[3] Kalra and Paddock. 2016. Driving to Safety. The RAND Corporation. https://bit.ly/3b5rqxa

Demonstrate Reliability

- Needed to demonstrate reliability in terms of fatalities and injuries.
- Driving alone is not feasible [1]:
  - Hundreds of billions of miles to be driven.
  - Tens / hundreds of years.
- Edge cases and dangerous situations / accidents not sufficiently addressed.
- Solution:
  - Systematic simulation of systems. OpenScenario, OpenDrive.
  - Testing: Software-in-the-Loop, Hardware-in-the-Loop, test track, public roads.

[1] Kalra and Paddock. 2016. Driving to Safety. The RAND Corporation. https://bit.ly/3b5rqxa

For Cars: PEGASUS

- Addressing safety of autonomous vehicles and how it can be assessed.
- Assessment of functionalities with robotic remote-controlled objects, for exact repeatability of testing scenarios.
- The Pegasus Method: framework for approval recommendation aimed at highly automated driving functions.
  - 20 steps, based on test cases, scenarios, and requirements management.
- Originally only for passenger vehicles, but could be modified for trucks.

[1] The PEGASUS Project https://www.pegasusprojekt.de/en/home

Challenges for Future Autonomous Trucks

- SAE-Level-2 ADAS products: ensure that driver is fully alert at any time.
- SAE-Level-3 products: ensure that control takeover from system to driver is seamless.
  - Autonomous systems may consider longer handover time.
- SAE-Level3+:
  - AI approaches (e.g. deep learning) have been hyped, are reaching limits.
  - Robustness of situation and scenario recognition is not yet sufficient. 99% ➔ 99.9999%
  - A lot of driving on public roads, but is still insufficient to prove reliability.
  - Insufficient data from edge cases (critical situations, accidents).
- Risk estimation and acceptance by automatic driving system. Literally following the traffic rules re. speed: will become obstacle.
- “Cooperation” with other non-autonomous vehicles .

Summary and Outlook

- The major breakthrough of autonomous truck deployment will most likely not be in SAE-Level 3, but in SAE-Level 4 systems.
- Strong emphasis on safety. Can only be achieved by taking into account more simulation, especially regarding edge case scenarios, to prove safety and robustness of technology.
- Autonomous trucks do have a strong business case, and it is very likely that in 10 years a significant percentage of autonomous trucks will be on highways.

Thank you!

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