The Intelligent Vehicles (R)evolution

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Mercedes-Benz
The best or nothing.

Things to Talk About

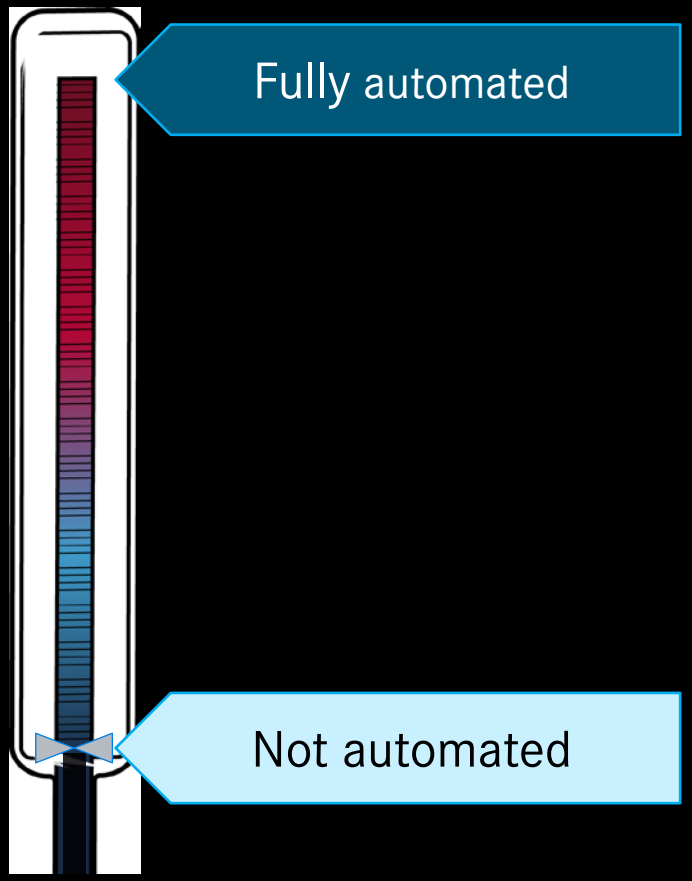
1. **What** can be automated in a vehicle: Products
2. **Why** vehicle automation makes sense: Motives
3. **How** an automated vehicle works: Technology
4. **Where** vehicle automation gets complicated: Challenges
5. **When** vehicle automation will come about: Timelines

1

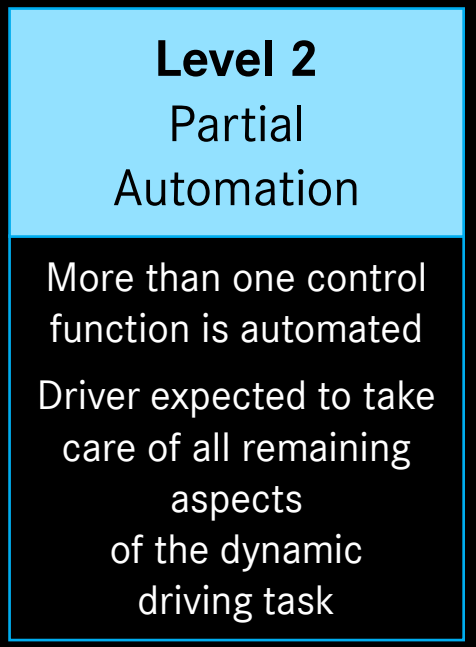
What can be automated in a vehicle:

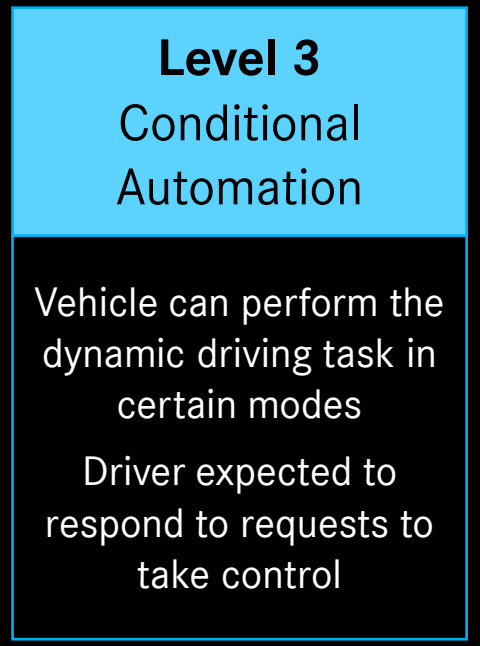
Vehicle Automation Products

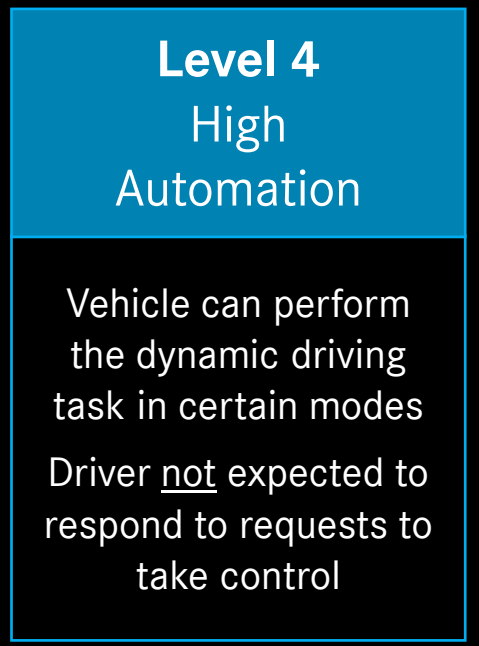
Degrees of Vehicle Automation

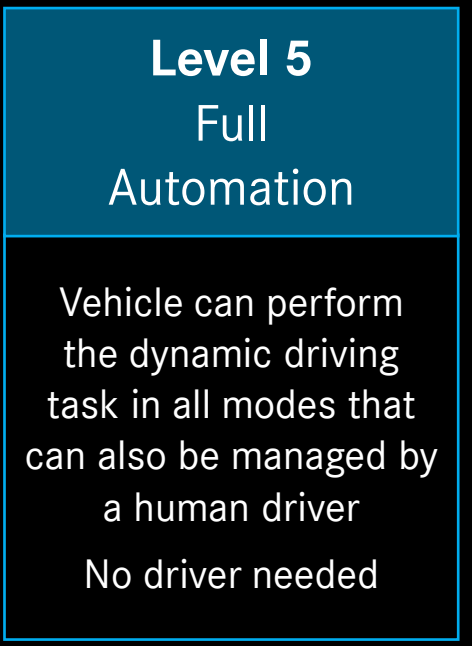


SAE Levels of Vehicle Automation









A More Meaningful Product-Driven Distinction

Version A ("Evolution")
Under Driver Control

Autopilot systems that are occasionally activated by the driver to take over

Version B ("Revolution")
Under Operator Control

Automated transport systems which drive the vehicle from source to destination

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Why vehicle automation makes sense:

Vehicle Automation Motives

Different Reasons for Vehicle Automation

The Safety Case
as made by many

Automation to improve traffic safety

The Mobility Case
as made by Google

Mobility for those who cannot drive

The Comfort Case
as made by us

Automation to meet customer demands

The Disruption Case
as made by analysts

Automation because it will be done

3

How an automated vehicle works:

Vehicle Automation Technology

Mercedes-Benz

Vehicle Automation Components

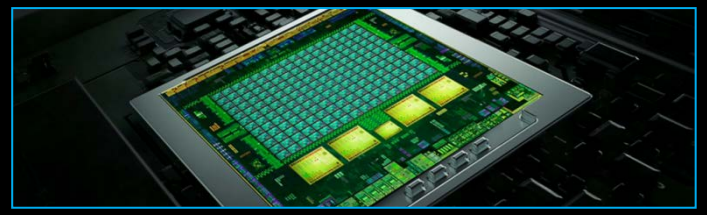
Sensors

What an autonomous vehicle does not "see",
it is likely to drive into

Actuators

Anything a driver would do
needs to be controlled electronically

Autonomous Vehicle "Brain"



Deciding which course of action is right
depending on the situation

Backend

Data provisioning and collection
as well as operator commands

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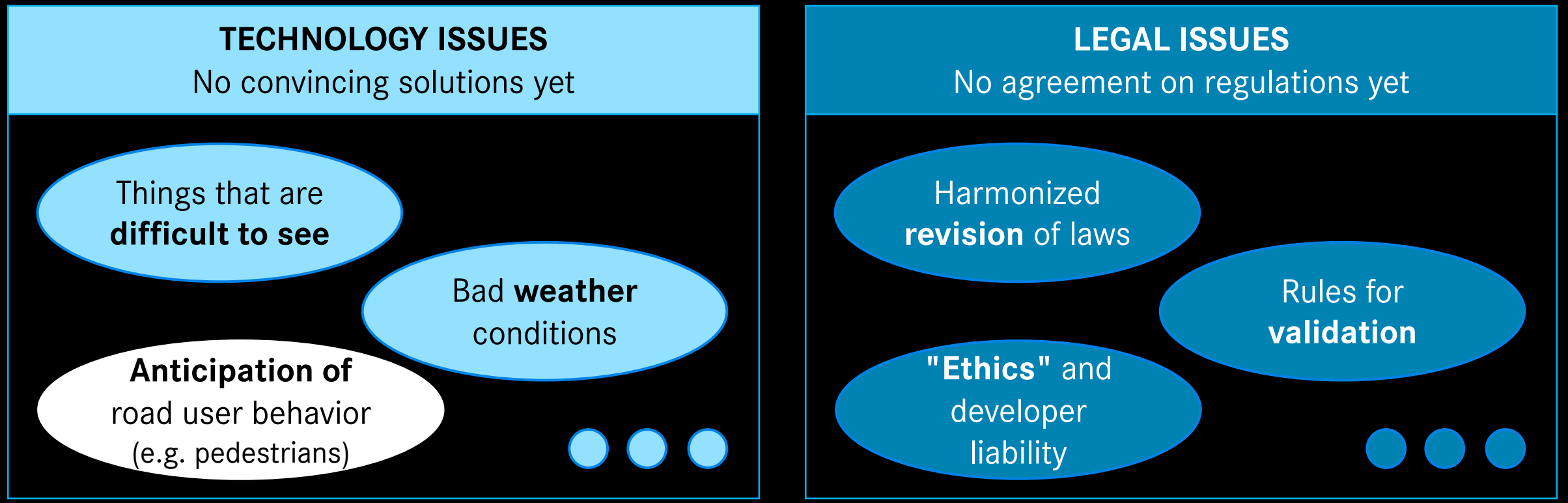
Where vehicle automation gets complicated:

Vehicle Automation Challenges

Some Vehicle Automation Issues Yet to be Solved

The perception that the technology is ripe and only current laws stand in the way is wrong.



And then there is customer acceptance, trust, and willingness to buy...

Limitations on Operating Conditions

Sensor performance is dramatically reduced under adverse conditions. Vehicle controllability may change.

Tunnels

Darkness

Heavy Rain/Snow

Low Friction

Sensor technology is under development, but how quickly will it become affordable?

Perception Insufficiencies for Certain Real-World Objects

Machine recognition and interpretation finds its limitations, esp. if only one sensor detects certain objects.

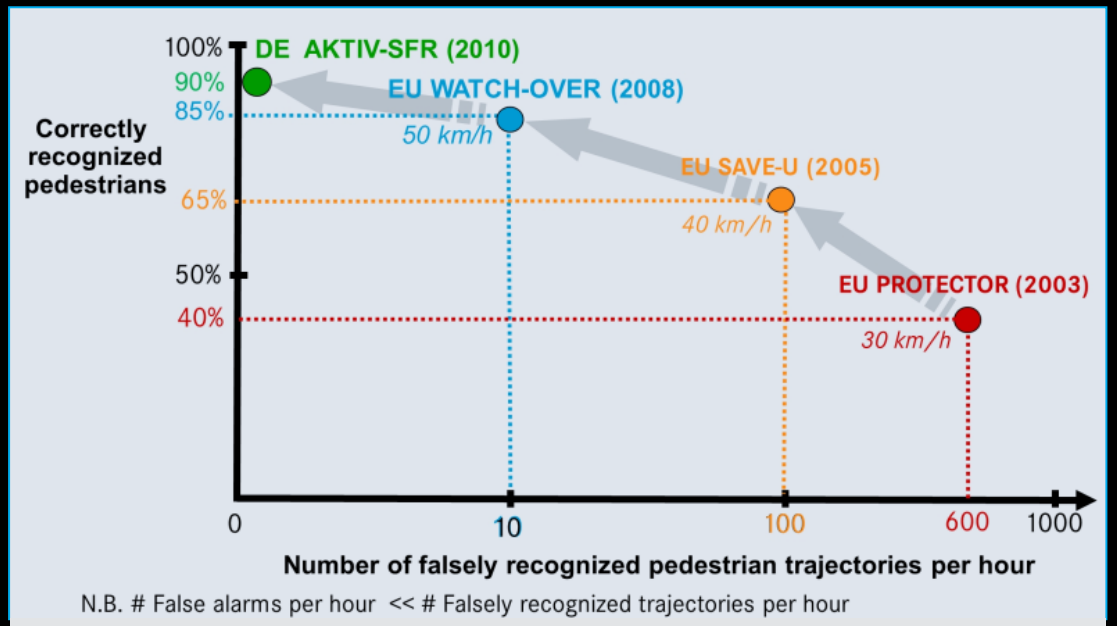
Traffic Lights
From easy to impossible

Road Debris
From small to big - from soft to hard

Areas where drives take place and speed of driving depend on sensor capabilities.

Perception Insufficiencies Interaction with Pedestrians

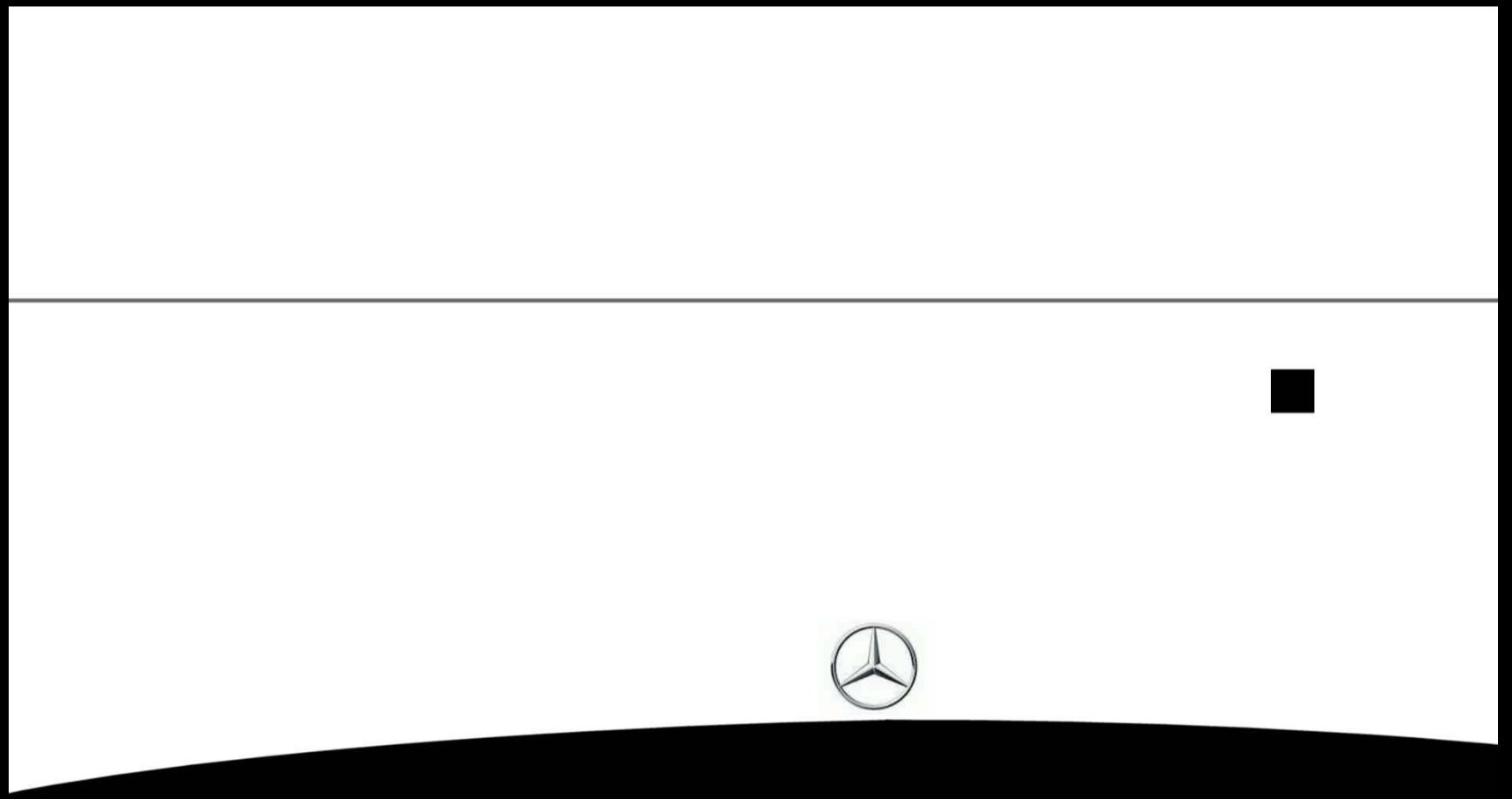
Progress on vision-based pedestrian detection
Last decade



What's next ?
Current Research

Pedestrian intent recognition
for anticipatory system action

Intent Recognition: Will the Pedestrian(s) Cross?

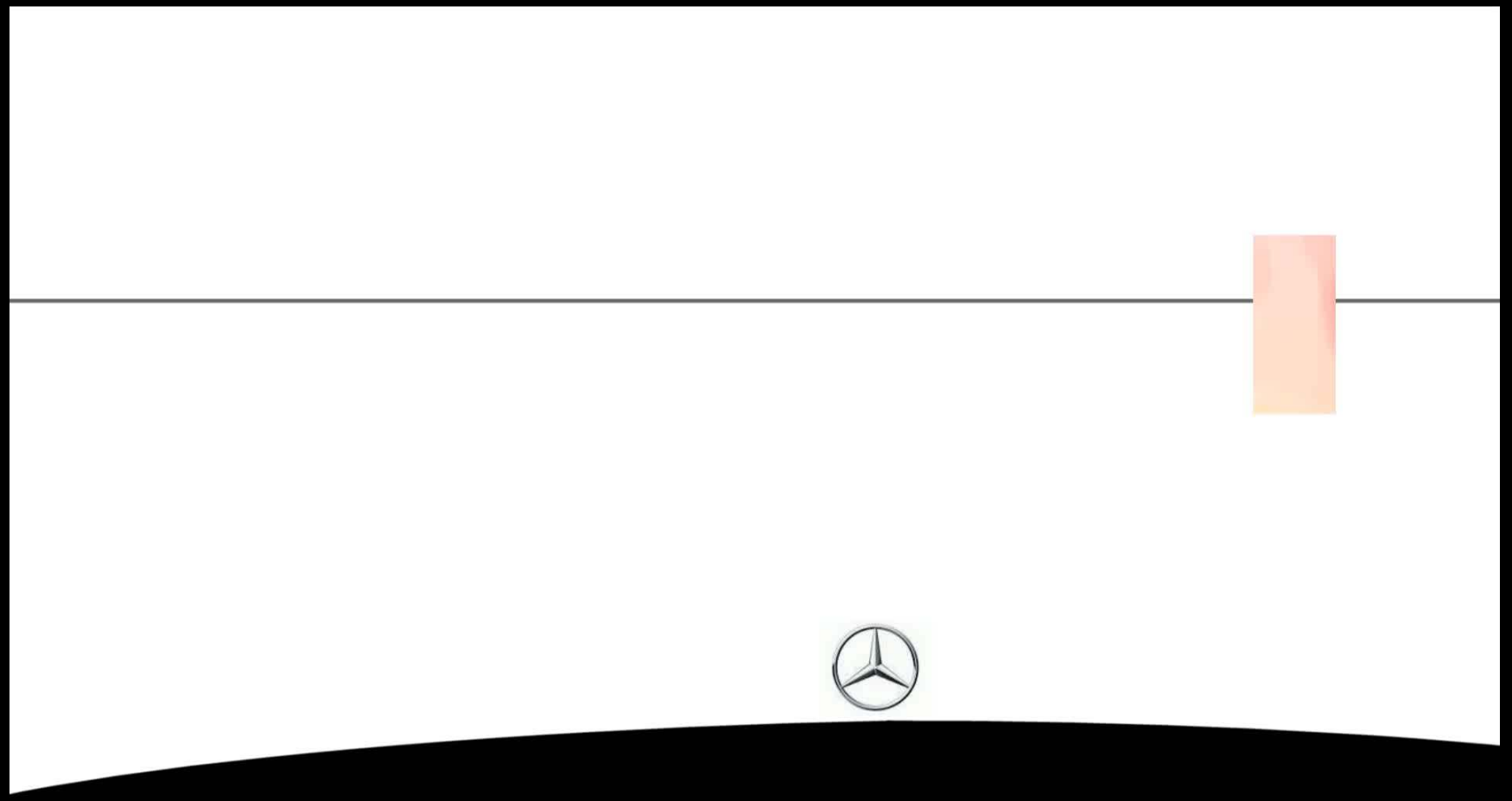


Current production vehicles only consider pedestrian point kinematics.

Difficult? Indeed, pedestrian crossing might be only detected when already underway in this way.

N. Schneider and D.M. Gavrila. Pedestrian Path Prediction with Recursive Bayesian Filters: A Comparative Study. *Proc. German Conf. on Patt. Recognition* 2013

Intent Recognition: Will the Pedestrian(s) Cross?



Point kinematics can be augmented with the image motion of the detected object.

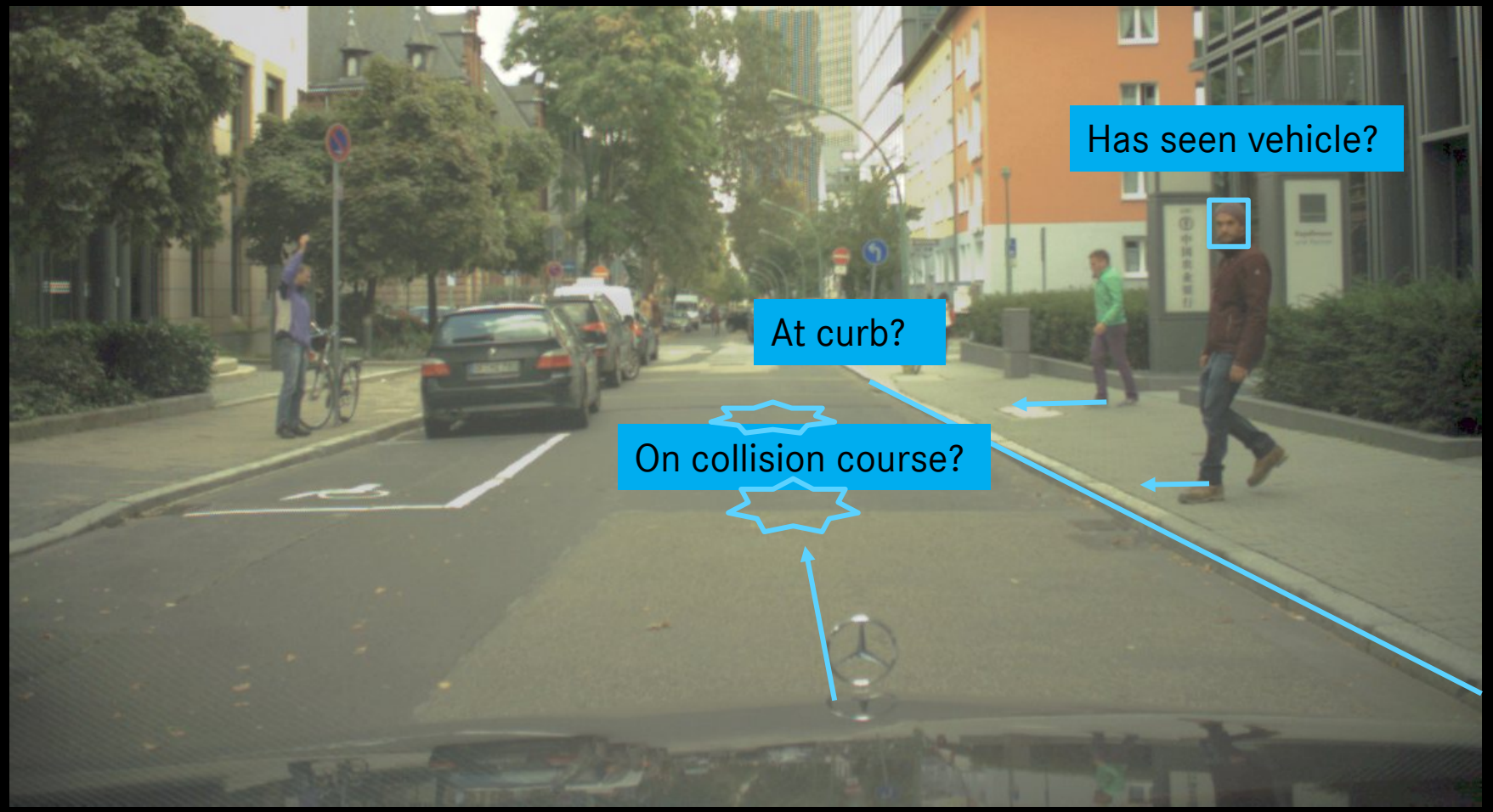
Augmented visual features allow machine learning algorithms to predict pedestrian crossing ~200 ms earlier.

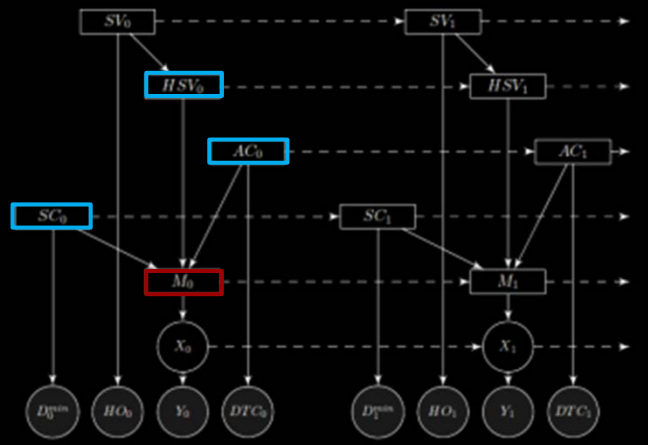
C. G. Keller and D. M. Gavrila. Will the Pedestrian Cross? A Study on Pedestrian Path Prediction. *IEEE Trans. on Intelligent Transp. Syst.*, vol.15, nr.2, 2014.

Intent Recognition: Will the Pedestrian(s) Cross?

A human driver relies heavily on context cues to anticipate how a traffic situation will evolve.

Intent Recognition: Will the Pedestrian(s) Cross?





Pedestrian Motion Modeling:
Dynamic Bayesian Networks

Various context cues influence the pedestrian motion

J. P. F. Kooij, N. Schneider, F. Flohr and D. M. Gavrila. Context-based pedestrian path prediction. *Proc. European Conference on Computer Vision* 2014.

Important for Intent Recognition:
Estimation of Pedestrian Torso & Head Orientation

Head and torso estimation takes into account physical constraints.

For clarity, results are only shown for one pedestrian at a time.

Various context cues influence the pedestrian motion

F. Flohr, M. Dumitru-Guzu, J. Kooij and D. Gavrila. Joint probabilistic pedestrian head and body orientation estimation. *Proc. Intelligent Vehicles Symp*, 2014.

Intent Recognition: Will the Pedestrian(s) Cross?

J. P. F. Kooij, N. Schneider, F. Flohr and D. M. Gavrila. Context-based pedestrian path prediction. *Proc. European Conference on Computer Vision* 2014.

Pedestrian Intent Recognition: „Live“ Demo (Crossing Case)

„New“ warning comes 1 second earlier !

High tone: „state-of-the-art“ warning, based on pedestrian point kinematics

Low tone: „new“ warning, based on context-based pedestrian motion modeling

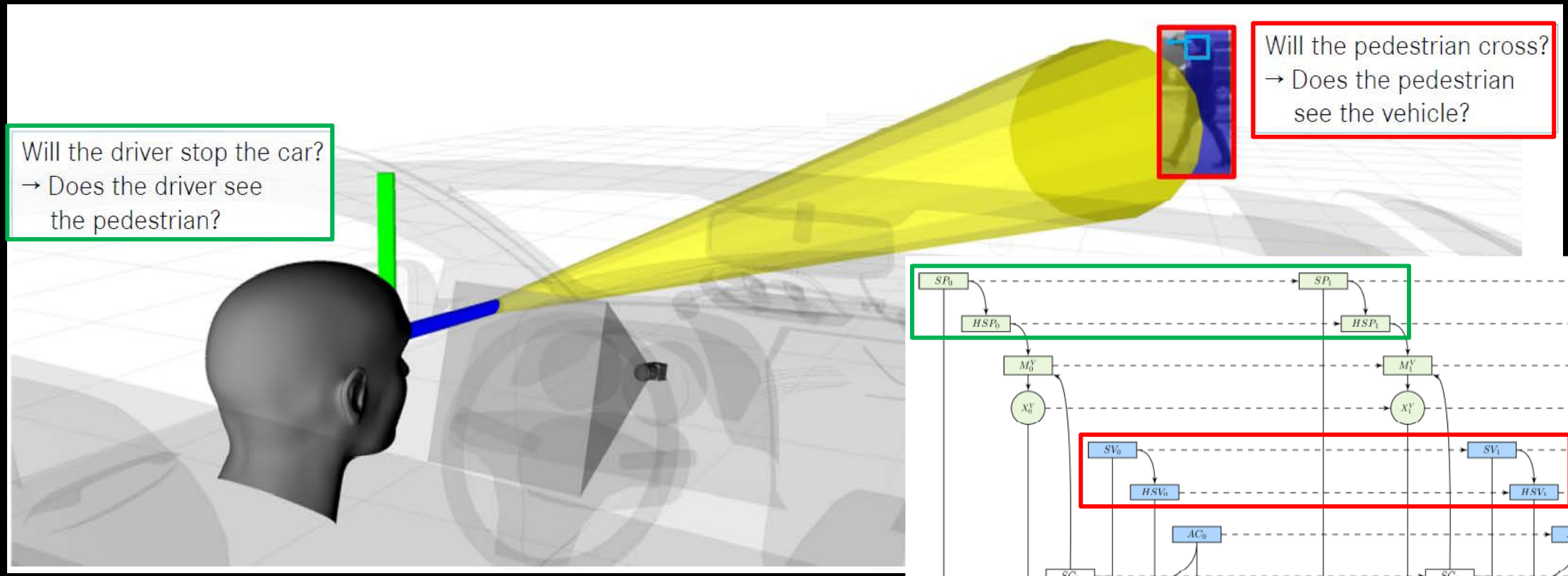
Pedestrian Intent Recognition: „Live“ Demo (Stopping Case)

No false alarm !

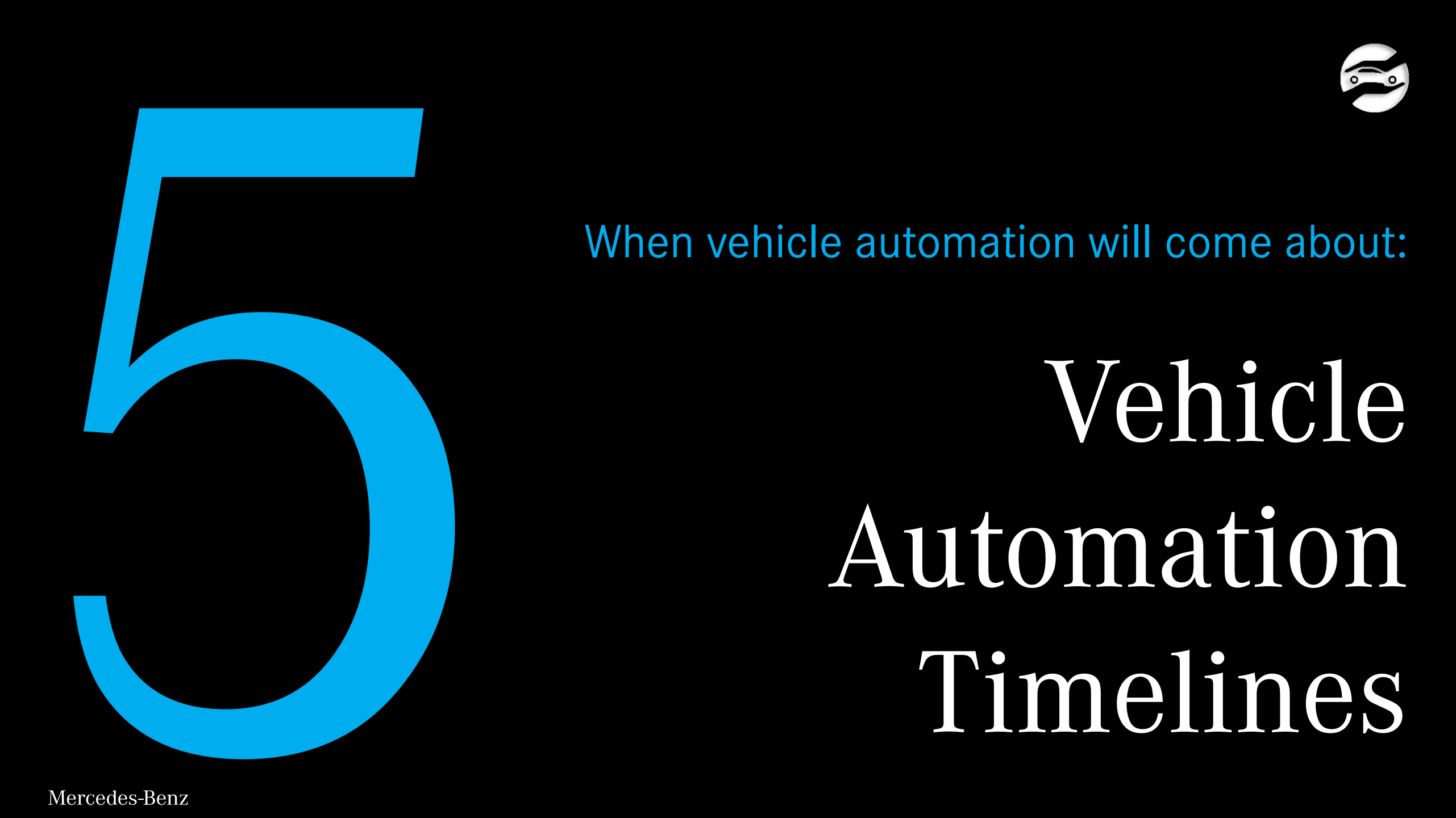
High tone: „state-of-the-art“ warning, based on pedestrian point kinematics

Low tone: „new“ warning, based on context-based pedestrian motion modeling

Joint Pedestrian and Driver Intent Recognition



M. Roth, F. Flohr and D. M. Gavrila. Driver and Pedestrian Awareness-based Collision Risk Analysis. *Proc. IEEE Intelligent Vehicles Symposium* 2016.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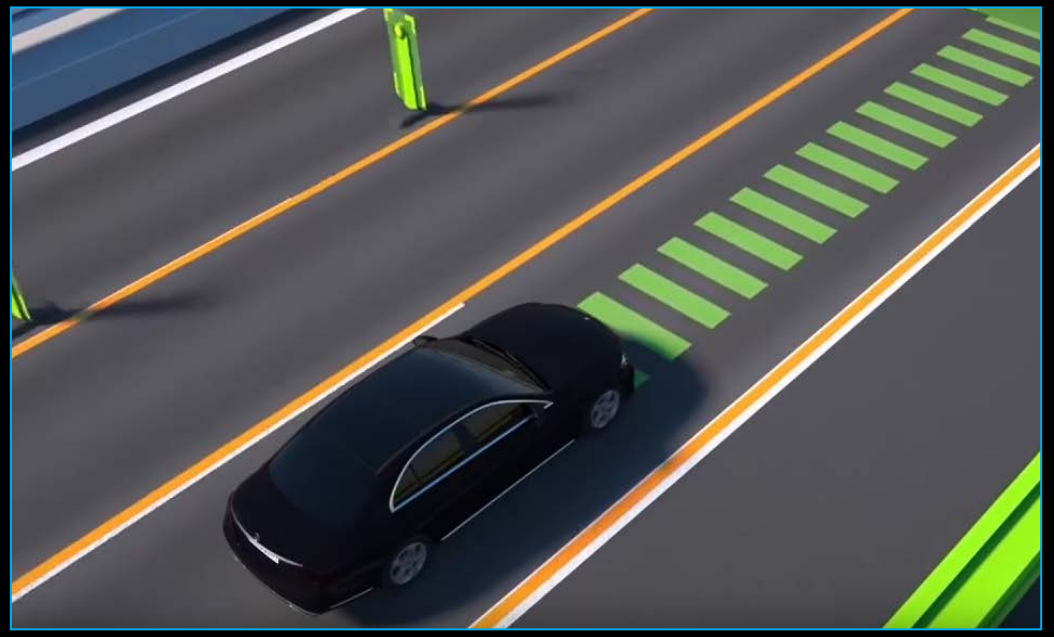
When vehicle automation will come about:
Vehicle Automation Timelines
Mercedes-Benz

Mercedes-Benz Vehicle Automation Today

Drive Pilot
in the 2016 E-Class



Following a lane with only occasional driver input
Changing lanes at the push of the indicator lever

Remote Parking
in the 2016 E-Class

Self-parking of the vehicle with external supervision
by the driver via smartphone

Mercedes-Benz Vehicle Automation Tomorrow

Urban Pilot
as demoed in the 2013 Bertha Benz Drive

Autonomous driving on mapped urban and rural roads within regular traffic

Automated Valet Parking
as currently prototyped with Bosch

Automatic parking and fetching of vehicles controlled and monitored by infrastructure

Automating Car Sharing Tomorrow

Public Transportation Tomorrow

Self-Driving Shuttle Busses
as currently tested in the WEPods project by TU Delft e.a. in Wageningen (NL)

Autonomous public transportation on dedicated routes

Which Automation When?

Systems appear in different forms, with different features, for different regions, and under different conditions:

Version A Under Driver Control	**Version B** Under Operator Control
Today: Mercedes-Benz Drive Pilot and Remote Parking Pilot Tesla and others with automation features *End of the decade:* Introduction of redundant actuators to support higher degrees of automation Focus on highway driving, but also on teaching and replaying certain routes	*Today:* Extensive testing by Google in Mountain View and Austin *Soon:* Testing by Uber in Tuscon First test installations of Automated Valet Parking *End of the decade:* First tests without safety drivers in favourable conditions (cars and bus shuttles)

Let's leave saying "In year X we will reach level Y automation" to the politicians.

Thank You For Your Attention!

Credits: R. G. Herrtwich and Daimler RD/FF colleagues