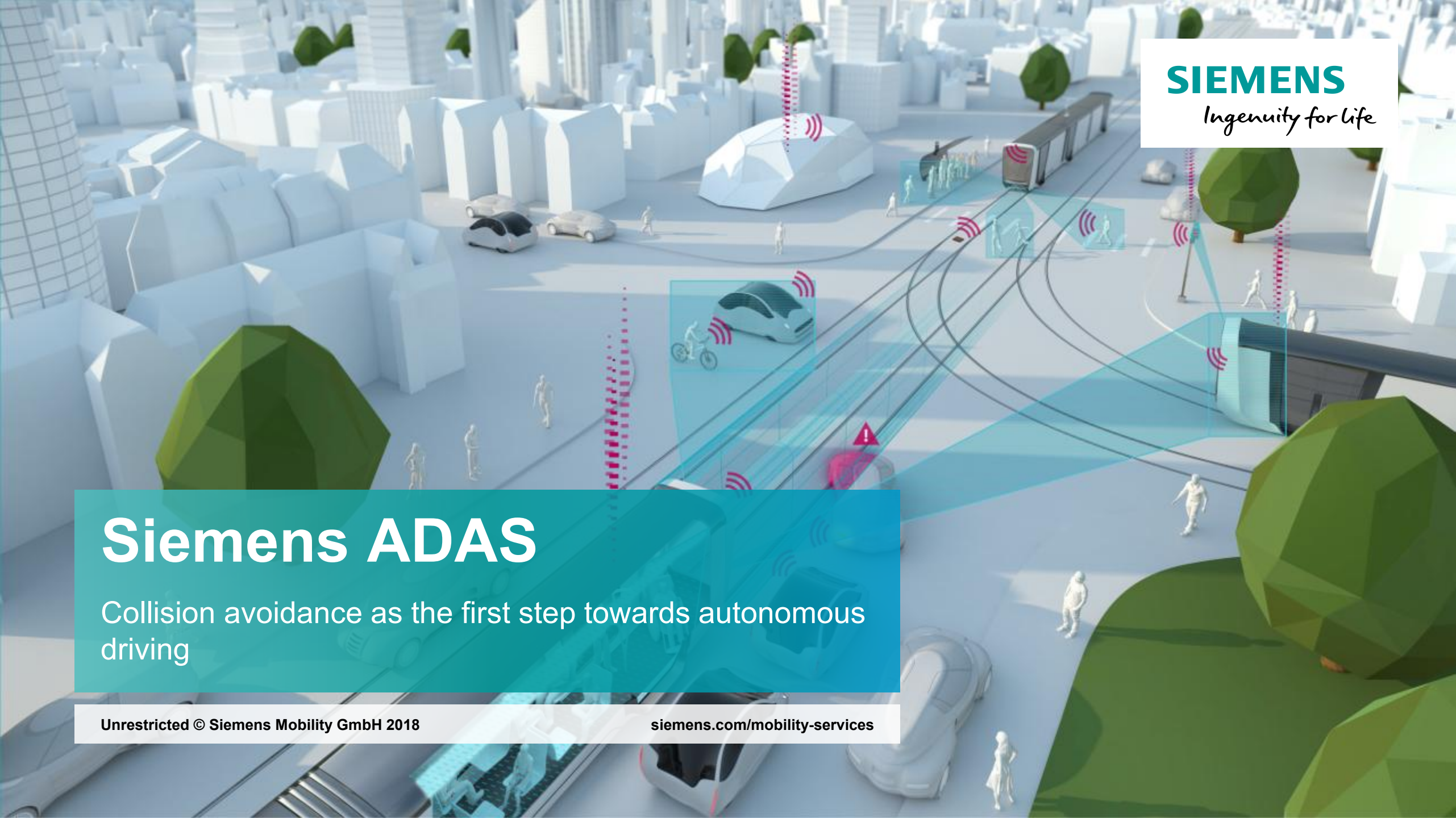

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Siemens ADAS

Collision avoidance as the first step towards autonomous driving

siemens.com/mobility-services

Advanced Driver Assistance Systems help to avoid collisions and represent the first step towards autonomous driving

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- Driver Assistance Systems are state-of-the-art in new cars
- Siemens ADAS transfers this technology to trams:
  - First step : collision avoidance system
  - Long-term target : autonomous driving
- Step-by-step iterations aligned with automotive developments

Development approach:

Siemens partners with Bosch and city of Ulm (running test lab)

ADAS Automotive vs. ADAS Rail
At first view automotive products seem to be easily usable

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The Task	• Sense environment • Assist driver or act autonomously
Used Sensors	• Radar, Camera, …
Detection task	• Detect other vehicles, obstacles, humans, animals etc • Consider traffic signs, signals, rules and regulations
All the same?	• Youthful optimism : use automotive ADAS on rail … • Technology is compact, inexpensive, already available, certified

ADAS Automotive vs. ADAS Rail
At closer inspection there are significant differences

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Automotive applications and environments	Rail applications and environments
Protected highway	Complex urban environment incl. operation in pedestrian areas or at crowded stops
Road vehicles and pedestrians	Additional LRVs and buffer stops
Detection of road markings (white on black)	Track detection (black on black)
Road signs and signals	Additional rail signs and signals, differently located
Concrete/asphalt road	Additional grass and ballasted track Embedded rails and standard rails
	Proximity to fixed installations, e.g. fences, poles
	Trackside rail-specific installations, e.g. stations, switch cabinets
	Far lower brake performance (due to limited friction)
	Non-buckled passengers
	Unwanted “gap filling” by automobiles in dense traffic

ADAS Automotive vs. ADAS Rail
The different applications require major adaptations for rail use

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To use automotive components in rail applications, adaptations have to be done …

- ➔Automotive ADAS sensors are highly specialized
- ➔Automotive market is priority (very large quantities and R&D budgets)
- ➔Adaptation of automotive components : small Rail market to cover one-time cost
- ➔Rail adaptations take time due to priority of automotive sector
- ➔Rail roadmap aligned with automotive sector : following market segment

Significant benefit to use automotive baseline developments to leverage synergies

Siemens ADAS system
Few components, straightforward installation, vehicle agnostic

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Tram Assistant

Controller

Camera

Radar

Combino Ulm

Core components are already proven in automotive and the entire system performance is qualified for the use in rail

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Multi Purpose Camera

Camera mounted in cab

- Detects the track
- Detects objects and their location in front of the tram

Mid-Range-Radar Sensor

Radar mounted in the front mask

- Detects objects by radar
- Measures object distance and velocity
- Fuses Camera and Radar data
- Determines if an object is a potential collision object

Rail Control Unit

Control Unit mounted inside tram

- Interface between the Siemens Tram Assistant system and tram
- Generates collision warning and braking signals
- Cancels signals in case of driver override
- System diagnostics (error codes)

** Source of pictures: Bosch Engineering*

The Siemens Tram Assistant detects and warns of hazardous situations with trams, cars, trucks, busses, buffer stops

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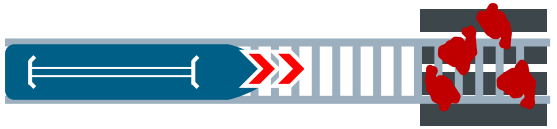
Use Case 1
Stationary cars, trucks, busses and trams at rear/front view

Use Case 2
Running or stopping cars, trucks, busses and trams at rear/front view

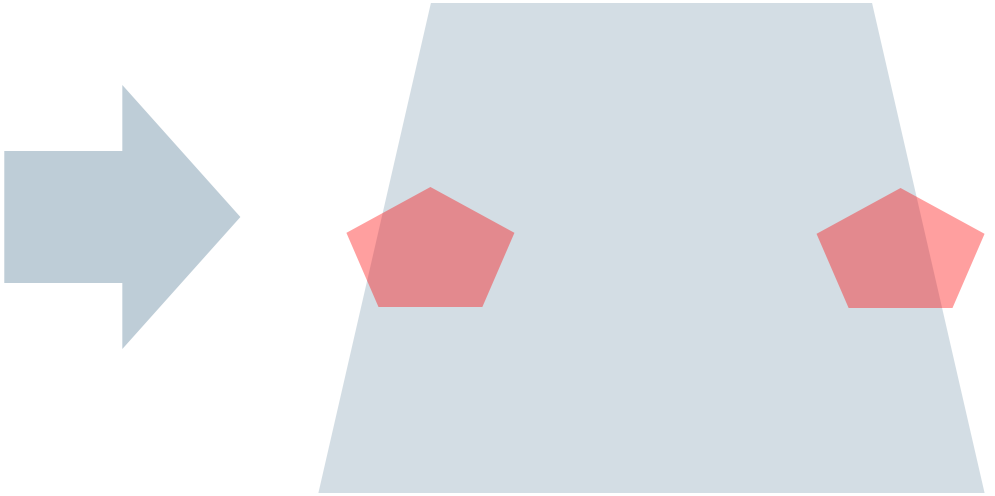
Use Case 3
Buffer stops, via attaching a radar reflector

Use Case 4 – under test
Completely visible and crossing pedestrians



Scenarios with potential high accident severity (e.g. tram-to-tram collisions) are covered.
Other scenarios are under development or evaluation and will be available via software upgrades.

Pattern recognition - trained shapes



Principle of system response of Siemens Tram Assistant

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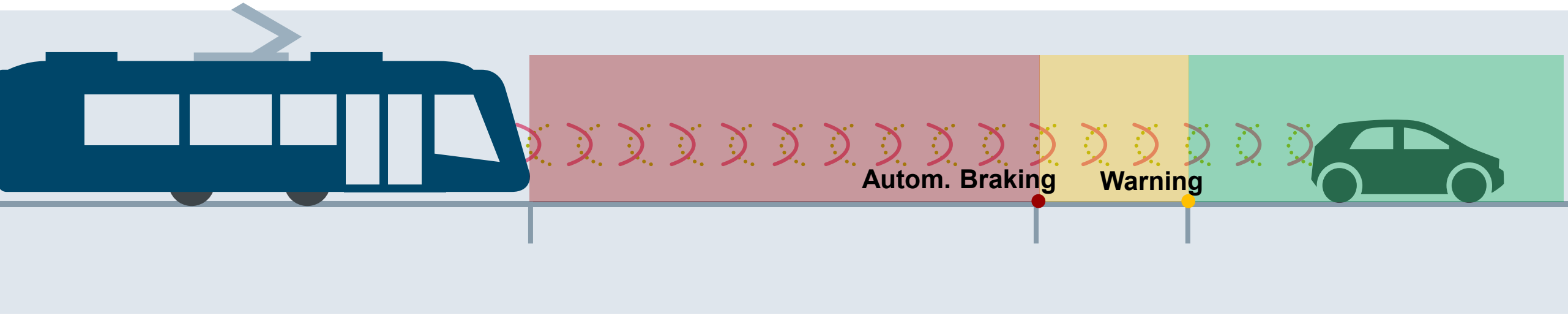
Warning/braking depends on

- Speed of the Tram
- Distance to the object

System calculates

- Stopping distance → Automatic braking
- Warning distance → Warning signal



Principle of system response : Siemens ADAS

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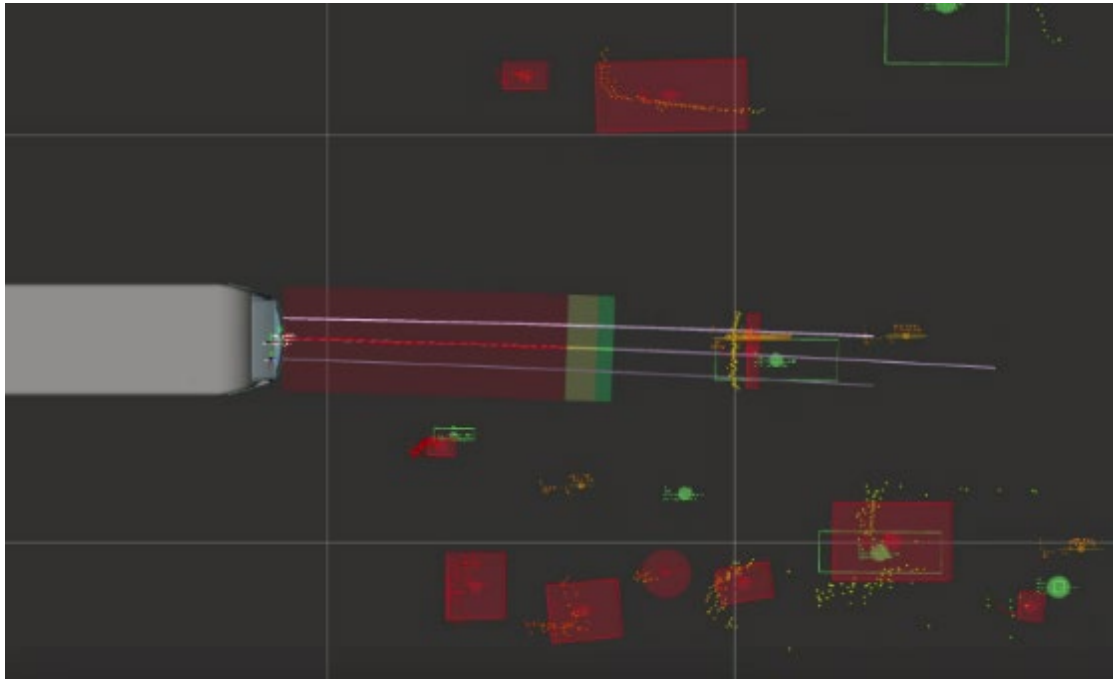

Camera View including system response strategy….

Object positioning laterally : Camera
Object positioning distance : Radar
Object type classification : Camera

Visualization of Camera View including system response strategy

Red : Objects detected by Radar
Green : Objects detected by Camera

Different levels of system integration for Siemens ADAS

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Integration level
Low

"Stand-alone-System" without integration : separate indicator/buzzer

Integration level
Medium

Hardwired signal to open safety loop

Integration level
High

SW Integration into train/brake control

Hardwired signal to initiate Full Service Brake. Driver can overrule the system reaction.

This system is a driver assistance system: Driver is responsible for driving by sight and should never rely on the system to respond

Safety and efficiency – the key factors in public transport

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Increased **safety** of all passengers and traffic participants	**Lower repair costs** by avoiding or reducing accident damage	**Higher availability of trams** thanks to reduction of accident frequency
Safety	**Cost efficiency**	**Availability**

Customer Feedback: Siemens Tram Assistant

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Tram drivers show behavioral change

- ➔Awareness of supervision
- ➔Conscious attempt to minimize system interference (incentive ?)
- ➔Higher focus on potential collision situations / geographical areas

Customers embrace new technology

- ➔Ulm and The Hague decided to retrofit their fleets (total 92 vehicles)
- ➔Bremen and Copenhagen ordered vehicles with ADAS (106 vehicles)
- ➔Standard requirement in European Tram tenders

Automotive roadmap towards fully autonomous driving

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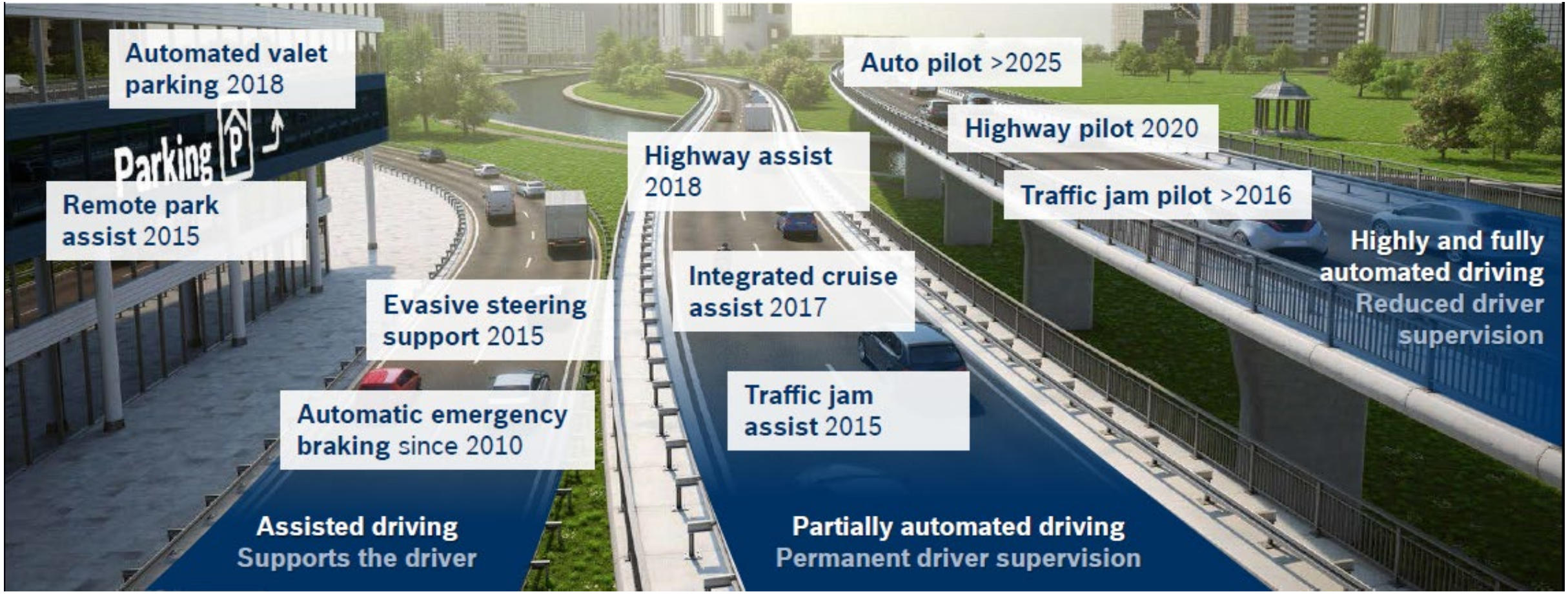

Source: Bosch AG

Conclusion

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- Assisted Driving for Trams is a reality
- Detecting Obstacles is easy : Responding correctly is hard
- Quick win to reduce severity of accidents on shared tracks