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## Teaching trams to drive.

On the way to smart and autonomous trams:  
A Siemens Mobility research project

[siemens.com/autonomous-tram](https://www.siemens.com/autonomous-tram)



# The trend: Urban transport goes autonomous

Over the past decades, trams have seen a worldwide renaissance. However, cars and buses are quickly becoming smarter and more autonomous, thanks to advanced sensor and automation technologies. To keep up and ensure their own long-term appeal and competitiveness, trams will have to develop into a smart, autonomous means of transportation.

## A tremendous vision with tremendous challenges:

- Open infrastructure: The smart and autonomous tram operates in mixed traffic with other traffic participants.
- A view ahead: The smart and autonomous tram needs to have a continuous overview of its environment and avoid collisions.
- On-board intelligence: The vehicle has to successfully master extremely complex traffic situations autonomously, without centralized, external control.



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# From assisted to autonomous driving

The way to the smart tram can only be realized in several stages. Driver assistance systems have proven effective for years. The next step followed in 2018, when Siemens Mobility put a research prototype of a smart, autonomous tram on the rails in Potsdam, Germany. Through daily experience in real-life urban traffic, the technology can now be continuously “trained” to improve its abilities in autonomous driving.

## The Siemens Tram Assistant

Several years ago, Siemens Mobility developed the Siemens Tram Assistant driver assistance system, a collision warning and prevention system that supports drivers.

The system is already being used successfully in trams in The Hague, Netherlands, and in Ulm, Germany. Bremen, Germany and Copenhagen, Denmark will soon be coming on board as well.

## Prototype of an autonomous tram

The next development level was launched in Potsdam, near Berlin. Siemens Mobility teamed up with Verkehrsbetrieb Potsdam GmbH (ViP) to test autonomous tram operation in real-life traffic – demonstrated live at InnoTrans 2018.

It was the first opportunity to observe how the tram of tomorrow reliably detects, intelligently evaluates, and autonomously reacts to complex situations.

*“The real feat is to safely drive the tram through street traffic with other traffic participants.”*

Ivo Köhler, Project Manager Autonomous Driving  
ViP Verkehrsbetrieb Potsdam GmbH

## Ready for the next level

Each test drive adds to the system’s existing knowledge about traffic and infrastructure situations. For example, if the sensors detect people in the immediate vicinity, the system’s intelligence has to make a decision: Is it approaching a routine stop or is there danger ahead, requiring it to brake immediately?

Using its many years of automation experience, knowledge of the specifics of trams’ operating environment, and powerful data analytics and artificial intelligence, Siemens Mobility is continuing to optimize the system and bring it closer to technological feasibility one step at a time.

## Assisted driving with the Siemens Tram Assistant

### Status quo:

Advance warning of collisions with trams, cars, trucks, and buses on the track

### Upcoming expansion:

- Pedestrian warning
- Speed monitoring

### Medium-term expansion:

More features derived from the automotive industry

## Step-by-step approach to autonomous driving

### Automated depot operation:

- Autonomous stabling and provision of vehicles
- Autonomous depot maneuvers, for example to washing plant

### Partially automated driving:

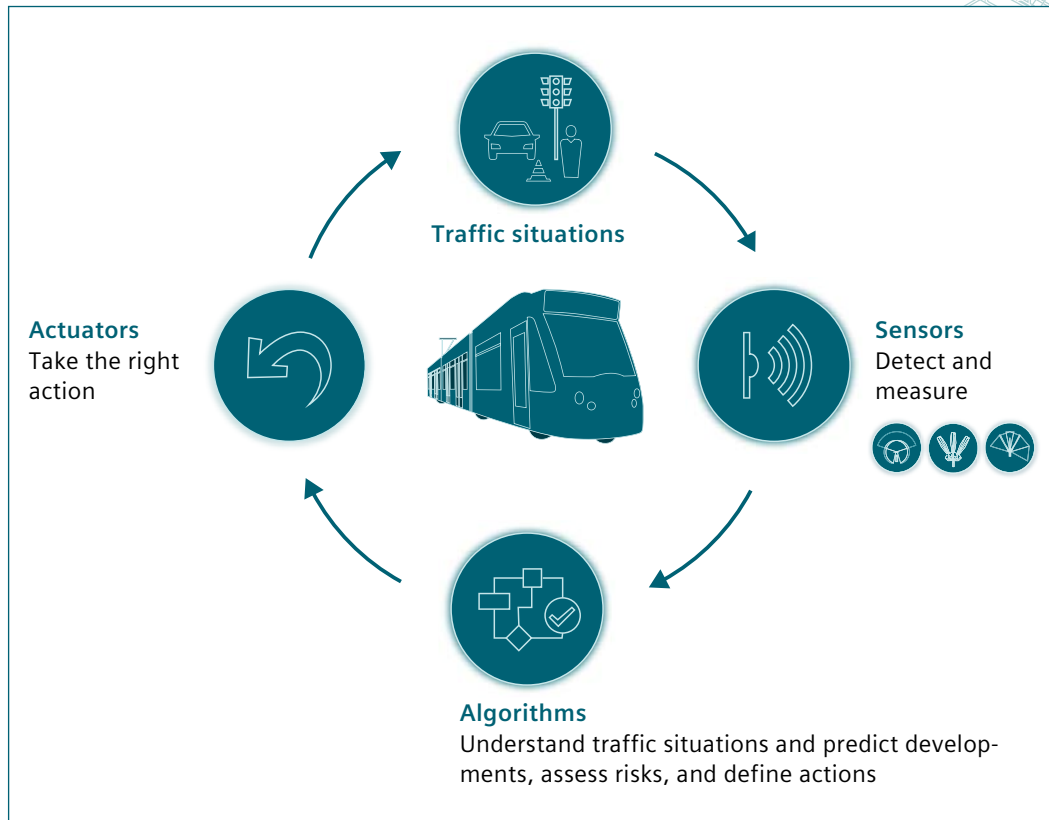
- Automation of specific line sections combined with collision avoidance
- Supervision by the driver

### Autonomous driving:

Including in complex urban environments with mixed traffic

# The eyes and brain of the system

What the automotive industry is doing to develop autonomous cars, buses, and trucks can often be leveraged for rail-bound public transportation, too. That's why Siemens Mobility relied on a number of proven technologies and principles when testing the smart and autonomous tram.



The vehicle reads its traffic environment using multiple lidar, radar, and camera sensors as its digital "eyes." At the same time, artificial intelligence using complex algorithms acts as the "brain" to interpret and evaluate the specific driving situation, predict future traffic developments, and trigger the necessary response on the part of the tram.

# A closer look: The three sensors

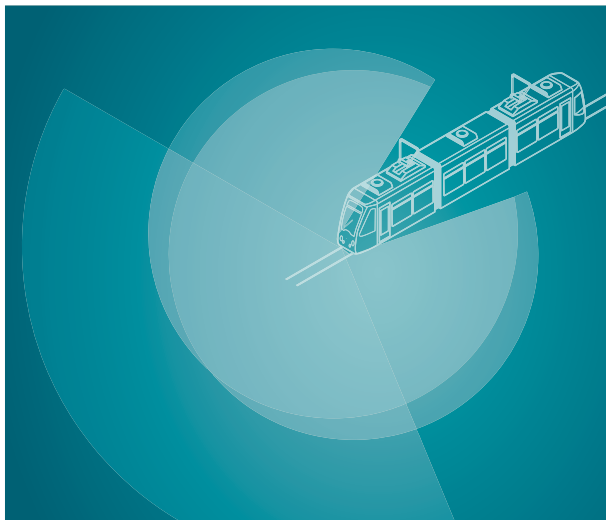
All three sensor types have their specific strengths. The fusion of their different perspectives provides a reliable basis for making decisions.



## Lidar

(light detection and ranging)

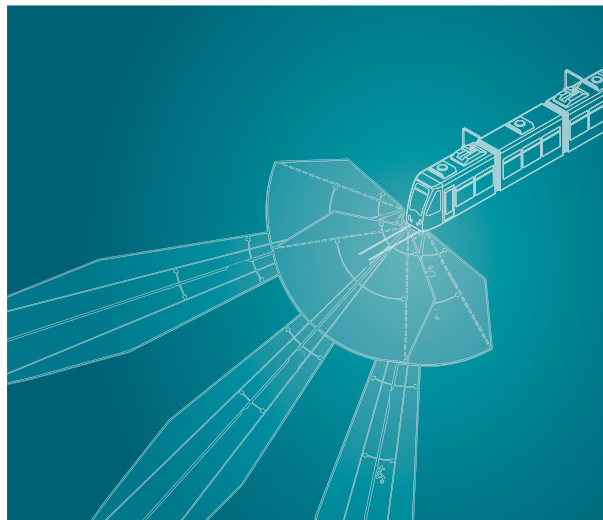
- Permits 3D measurement and positioning of objects
- Scans objects both vertically and horizontally using laser beams; uses reflected waves to perceive environment
- Gives the tram a 270° view



## Radar

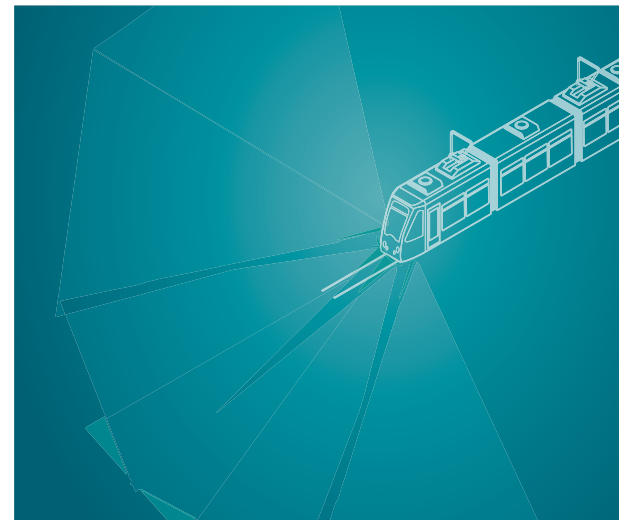
(radio detection and ranging)

- Measures distance and speed, especially of metallic objects, with extreme precision
- Sends out radio waves and uses the reflected waves to detect objects
- Senses a wide range of the environment ahead of the tram



## Cameras

- Are trained in intelligent object and signal recognition
- Can recognize and classify objects in thousands of shapes and positions, such as people, signals, or infrastructure elements
- Cover a wide optical range surrounding the vehicle





# Life isn't programmable. The future of trams is.



## Approaching a signal

### 1. Sensors read the environment

- Signal ahead
- Status: "Stop" or "Prepare to stop"
- Own speed and distance to signal

### 2. Algorithms evaluate and conclude

- "Moderate braking down to standstill"
- "Start driving again when signal switches to go"

### 3. Actuators take the right action

Adjust speed down to zero or accelerate and continue driving



## Approaching a station

### 1. Sensors read the environment

- Station ahead
- People are standing too close to the platform edge
- Own speed and distance to people

### 2. Algorithms evaluate and conclude

"Signal a warning"; if no reaction, then  
"Brake and stop in front of the detected object"

### 3. Actuators take the right action

Trigger warning bell, then adjust speed down to zero



Pedestrians, crossing vehicles, stations, signals ...  
The research prototype of the smart and autonomous tram  
is learning to master all important situations from real-life  
traffic experience in Potsdam.



### Crossing vehicles

#### 1. Sensors read the environment

- Moving object on the track
- Current speed of vehicle and tram
- Distance to vehicle

#### 2. Algorithms evaluate and conclude

Ring bell to warn? Brake? Prepare to stop?

#### 3. Actuators take the right action

Adjust speed down to zero



### Crossing pedestrians

#### 1. Sensors read the environment

- Moving object on the track
- Current speed of pedestrians and tram
- Distance to pedestrians

#### 2. Algorithms evaluate and conclude

Ring bell to warn? Brake? Prepare to stop?

#### 3. Actuators take the right action

Adjust speed down to zero



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