



# Automated driving Intelligent Transportation Systems

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Rolland Vida

# Unmanned systems and vehicles

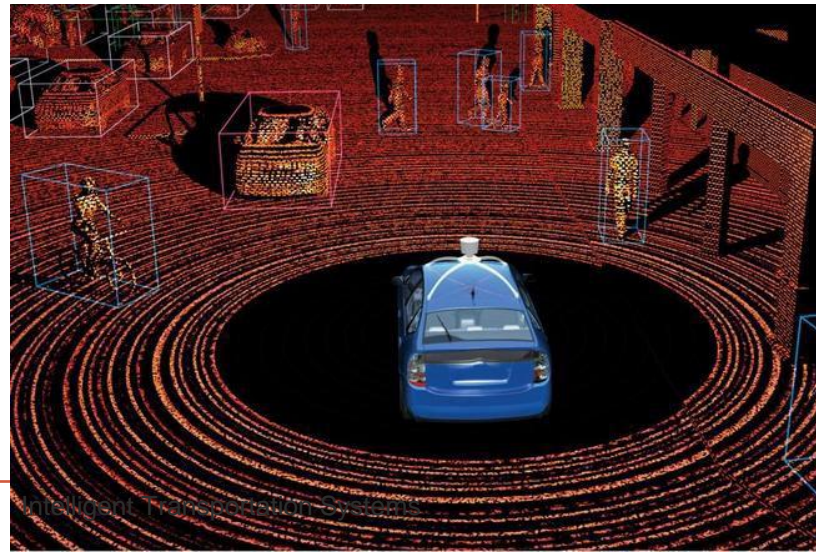
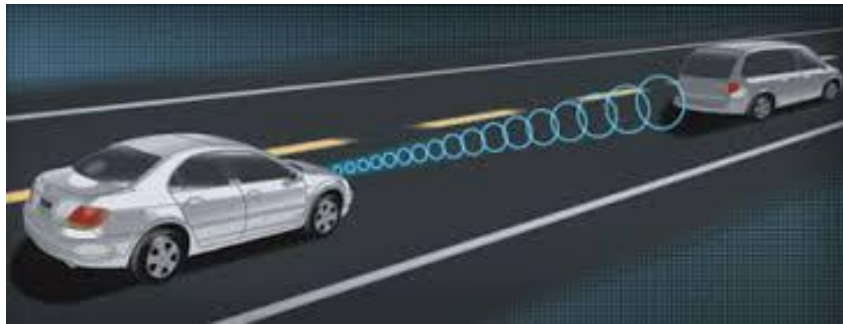
- **Unmanned system:** any electro-mechanical system which has the capability to carry out a prescribed task or portion of a prescribed task automatically, without human intervention
- **Unmanned vehicle:** a vehicle that does not contain a person
  - Can be tele-operated
  - Can be autonomous – takes decisions independently
- Unmanned vehicles can come in several flavors: **UxV**
  - Land: UGV (Unmanned Ground Vehicle)
  - Air: UAV (Unmanned Aerial Vehicle)
  - Maritime: UUV, USV (Unmanned Underwater / Surface Vehicle)





# Autonomous / Self-driving cars

- A vehicle capable of sensing the environment, and navigating without human input
- Different techniques to detect their surroundings
  - **Radar** (RAdio Detection And Ranging) – radio waves to determine range, angle and velocity of objects
  - **Lidar** (LIght Detection And Ranging) – illuminating the target with a pulsed laser light, and measuring the reflected pulses
  - **Odometry** (*odos* – route, *metron* – measure) – use motion sensor data to estimate position change over time, relative to a starting location
  - **Computer vision** – detect other cars, objects on the road, road signs, traffic lights, based on image processing, machine learning and artificial intelligence



# Autonomous / Self-driving cars

## ▪ Benefits

- Reduced mobility costs (no driver needed)
- Enhanced mobility for children, disabled and elderly people
- Increased safety, increased consumer satisfaction, increased traffic flow, lower fuel consumption
- Less need for insurance

## ▪ Obstacles to widespread adoption

- Technological challenges – **less and less**
- Disputes on liability in case of accidents
- Long time period to replace the existing stock of vehicles
- Resistance of individuals to hand over the control
- Implementation of regulations, legal framework
- Privacy and security concerns (car hacking)
- Loss of driving-related jobs

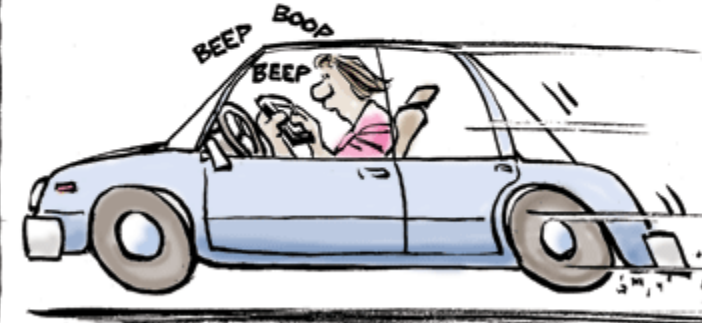


*"Does your car have any idea why my car pulled it over?"*

**NEWFANGLED  
DRIVERLESS CAR:  
NO STEERING  
WHEEL**



**OLD-FANGLED  
DRIVERLESS CAR:  
NO BRAIN**



# What does automated driving mean?

- **SAE International – Society of Automotive Engineers**
  - Professional association and standards developing organization
  - Automotive, aerospace, and commercial vehicles
  - More than 138.000 individual members worldwide
  
- **Standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (2014)**
  - Identifies six levels of driving automation from “no automation” to “full automation”
  - Describes categorical distinctions for a step-wise progression through the levels
  - Eliminates confusion, useful across numerous disciplines (engineering, legal, media)
  - Educate a wider community by clarifying for each level what role (if any) drivers have in performing the *dynamic driving task* while a driving automation system is engaged.

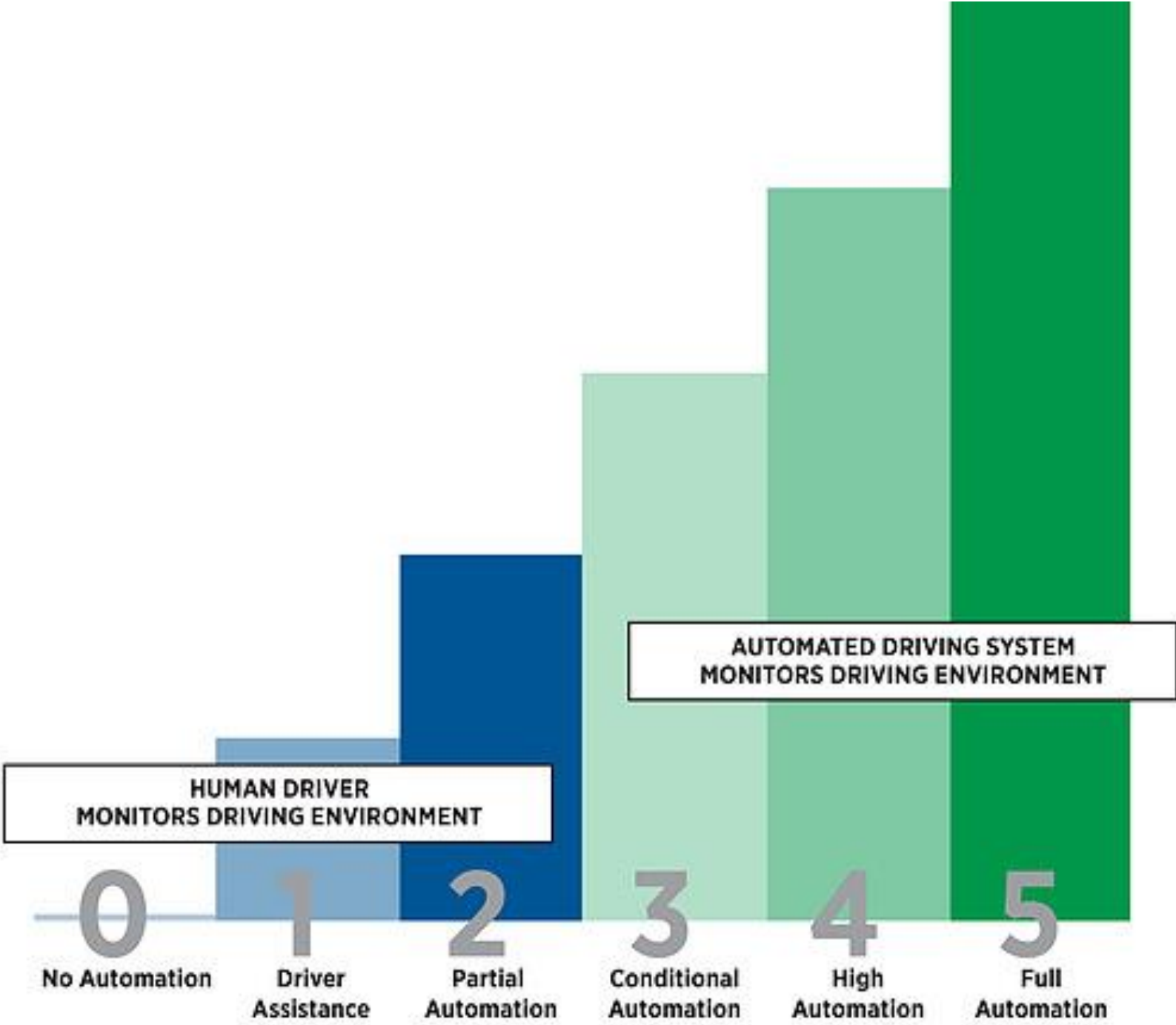


# Taxonomy

- **Dynamic driving task**
  - Includes **operational aspects**
    - Steering, braking, accelerating, monitoring the vehicle, monitoring the road
  - Includes **tactical aspects**
    - Responding to events, deciding when to change lanes, turn, use signals
  - *Does not include* **strategic aspects**
    - Determining destinations and waypoints
- **Driving mode**
  - Type of **driving scenario** with specific dynamic driving task requirements
    - Expressway merging, high speed cruising, low speed traffic jam, etc.
- **Request to intervene**
  - Notification by the automated driving system to a human driver that he/she should promptly begin or resume performance of the dynamic driving task
- **Autonomous vs. Automated**
  - Autonomous – self governance, taking decisions independently
  - Automated – operates, takes decisions without human intervention
  - **Automated more accurate, but autonomous more widespread**



# Levels of automation



SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of <i>Dynamic Driving Task</i>	System Capability ( <i>Driving Modes</i> )
<b>Human driver monitors the driving environment</b>						
<b>0</b>	<b>No Automation</b>	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
<b>1</b>	<b>Driver Assistance</b>	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
<b>2</b>	<b>Partial Automation</b>	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	<b>System</b>	Human driver	Human driver	Some driving modes
<b>Automated driving system ("system") monitors the driving environment</b>						
<b>3</b>	<b>Conditional Automation</b>	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	<b>System</b>	Human driver	Some driving modes
<b>4</b>	<b>High Automation</b>	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	<b>System</b>	Some driving modes
<b>5</b>	<b>Full Automation</b>	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	<b>All driving modes</b>



# Levels of automation

- **Level 0 (no automation)** – The human driver controls all (steering, brakes, throttle, power)
  - Only warnings from the automated system
- **Level 1 (driver assistance)** – „hands on”
  - Most functions still controlled by the driver
  - One function (steering **OR** acceleration) done automatically by the car
  - Driver must be always ready to take over the full control
  - E.g., **adaptive cruise control** – driver controls the steering, the automated system controls speed
  - E.g., **parking assistance** – driver controls speed, the automated system controls steering
- **Level 2 (partial assistance)** – „hands off”
  - Driver is disengaged from physically operating the car
  - Hands off the steering wheel **AND** foot off the pedal at the same time
  - Driver must be always ready to take back the control of the vehicle
    - Often, the hand is required to be on the steering wheel, to confirm that the driver is ready to take over control, if needed

# Levels of automation

- **Level 3 (conditional automation)** – „eyes off”
  - Driver not required to monitor the environment anymore
    - The system (vehicle) does it, the driver can watch a movie
  - Driver still present and will intervene if needed
    - Within a limited amount of time, specified by the manufacturer
    - The car will handle emergency situations (e.g., fast braking)
  - First commercial car at level 3 – **Audi A8 Luxury Sedan**
    - Traffic Jam Pilot
    - Slow-moving traffic, up to 60 km/h, on highways, physical barrier for the opposite lane
  - Some manufacturers (e.g., Ford) want to skip this level
    - If the driver does not have to monitor the environment, you cannot expect from him to intervene



# Levels of automation

- **Level 4 (high automation)** – „mind off”
  - Vehicles perform all safety-critical driving functions, and monitor the roadway conditions
  - Driver may go to sleep, or leave the driving seat
  - It does not cover all driving scenarios, only limited areas (geofencing) or special conditions (traffic jam)
    - Outside these scenarios, the vehicle must safely abort the trip, park the car, until the driver retakes control
- **Level 5 (full automation)** – Equal the human driver in every driving scenario
  - Extreme environments and road conditions (e.g., dirt roads)
  - Driverless vehicles not expected at this level in the near future



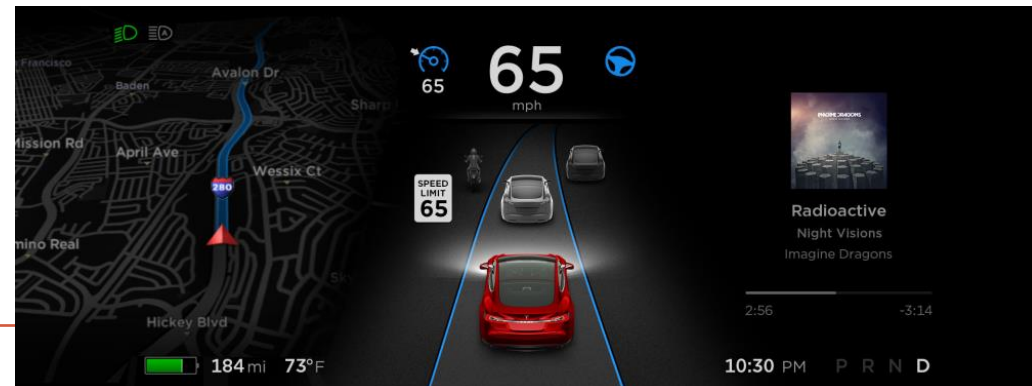
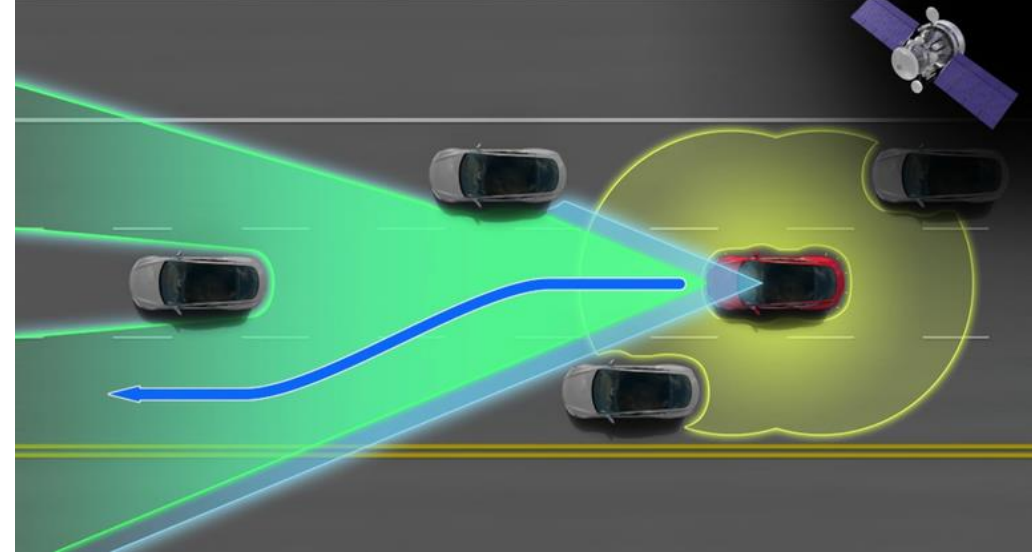
# History of automated cars

- Experiments since the 1920s, promising trials from the 1950s
- General Motors Firebird II (1956)
  - For the „highway of the future”
  - Electric wire embedded in the road sends signals to guide the car
- First truly autonomous prototype cars in the 1980s
- ParkShuttle in the Netherlands, Schiphol Airport (1997)
  - World’s first driverless vehicle
  - Magnets embedded in the road surface
- Would they be allowed on public roads?
  - In 2015, allowed in Nevada, California, Florida, and some other states
  - Test circuit is build now near Zalaegerszeg, Hungary



# Tesla Autopilot

- **Autopilot 8.0** – October 2014
  - Tesla Model S and X, Level 2 (partial assistance)
  - Assist highway driving, enable cars to self-steer, adjust speed, detect nearby objects, apply brakes and park
  - Driver advised to keep his hands on the steering wheel
  - Forward looking radar (up to 150 meters) – detect the vehicle's surroundings
  - Front camera – backup for the radar, can see traffic signs, traffic lights
  - Sonar – 360 degrees, 12 ultrasonic sensors, detect nearby obstacles (children, dogs, cars in blind spot)
  - GPS, navigation system – automatically change lanes and exit freeway
    - Activated also with the turn signal





# Tesla Autopilot

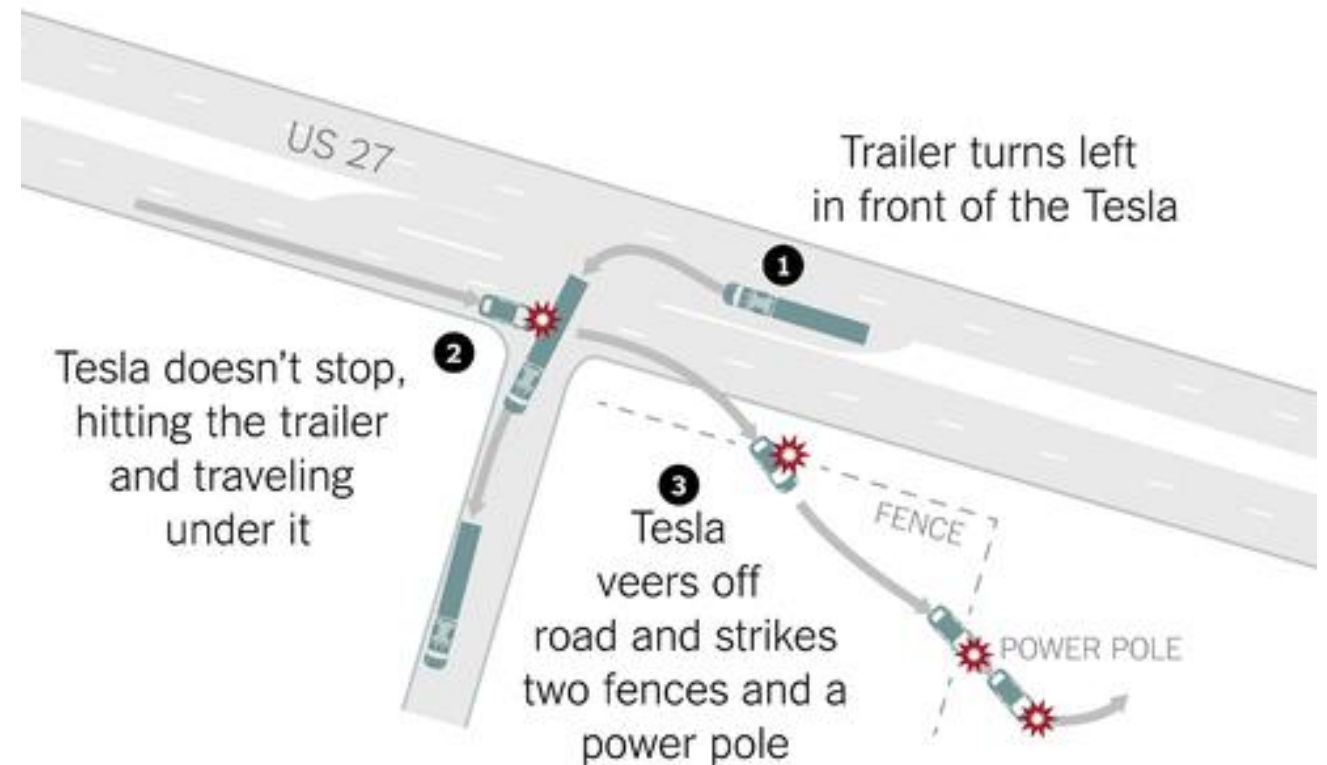
- Autopilot 8.1 (Enhanced Autopilot) – October 2016
  - Equip all cars with the hardware necessary for self-driving cars
    - Just a software update, when software is ready, safe and mature enough to be activated
  - 8 cameras instead of the single front camera
    - 4 currently active, 4 will become active later, in the „fully self-driving mode”
  - 360 degree vision extended to 250 meters
  - In fully self-driving mode, just tell the car your destination
    - If not, it guesses from your calendar
    - Or it takes you home
    - Let you off and park itself later





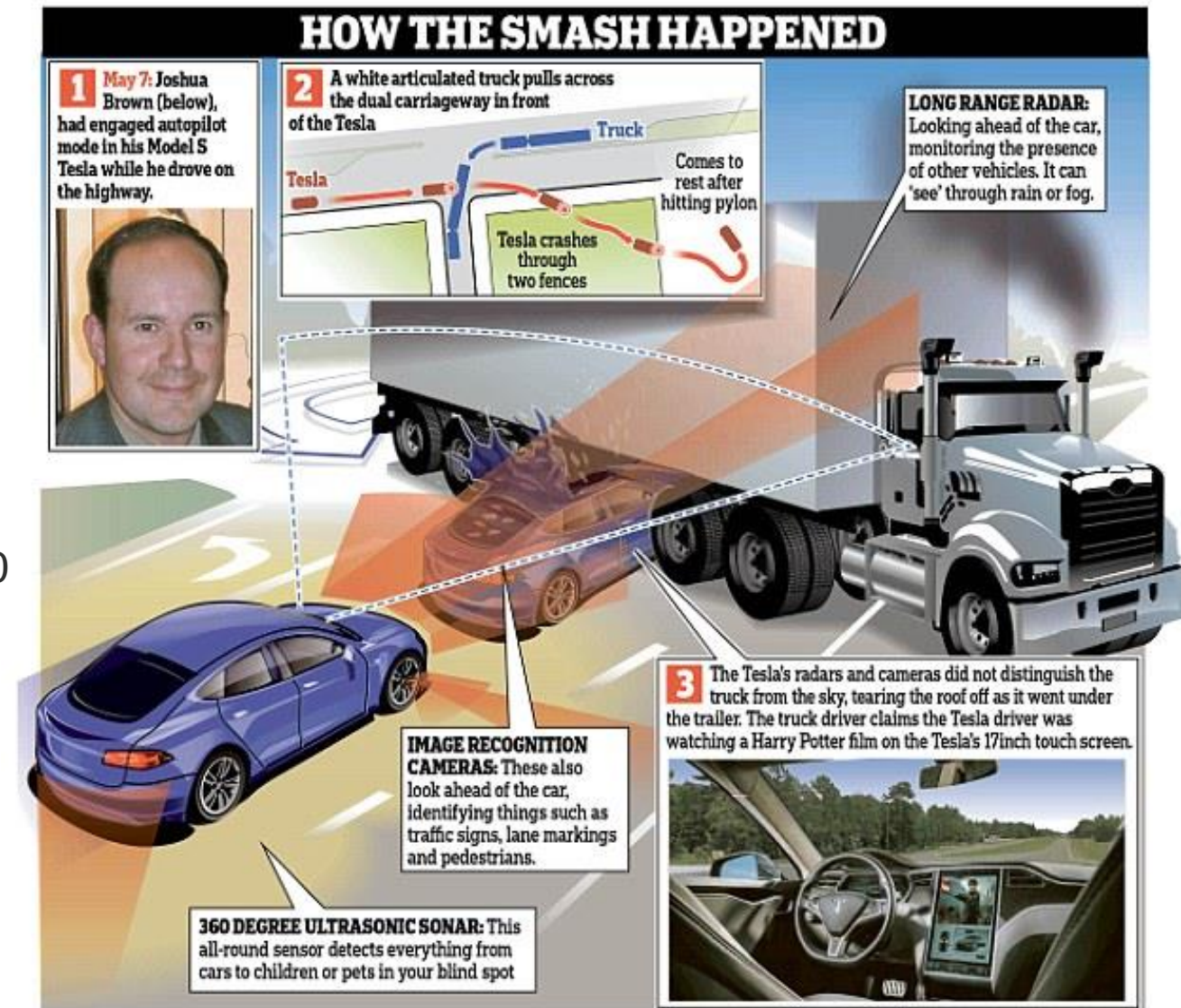
# First fatality with Tesla Autopilot

- In May 2016, Joshua Brown died, while using Autopilot mode
- The car struck a tractor trailer that turned left, and crossed the path of the Tesla
- Could not distinguish the white side of the trailer from the bright sky (in sunny weather)



# First fatality with Tesla Autopilot

- Engaged a long debate on self-driving cars
  - Although it was not a „self-driving car”, just level 2 (partial assistance)
- First fatality after 130 million miles
  - For regular cars US average 1,3 deaths / 100 million miles
- Self-driving cars will make traffic safer
  - Number of accidents decreased with 80% by 2040
- New business model for insurance companies
  - They need also a classification regarding the different levels of automation / autonomy



# Ethical issues

- What is the ethical decision to take in case of an unavoidable accident?
  - Minimise the death toll?
  - Protect the passengers in the car?

