



Automated driving

Intelligent Transportation Systems

Rolland Vida

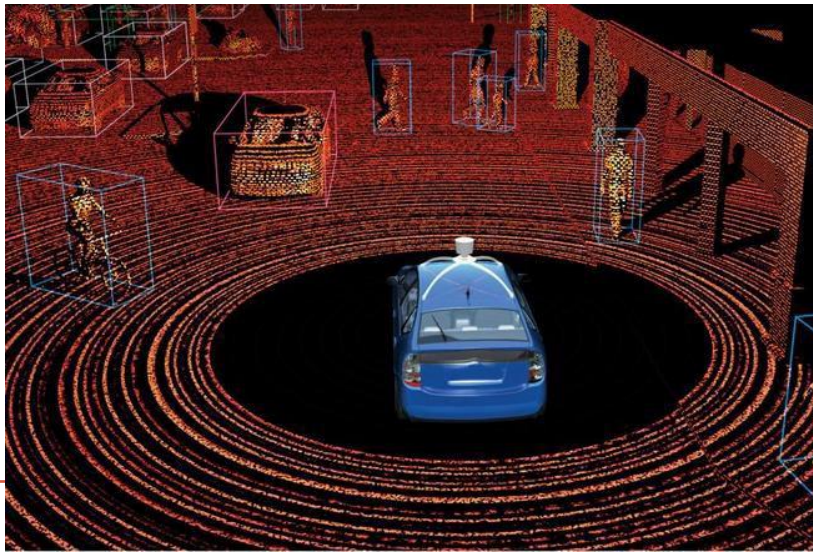
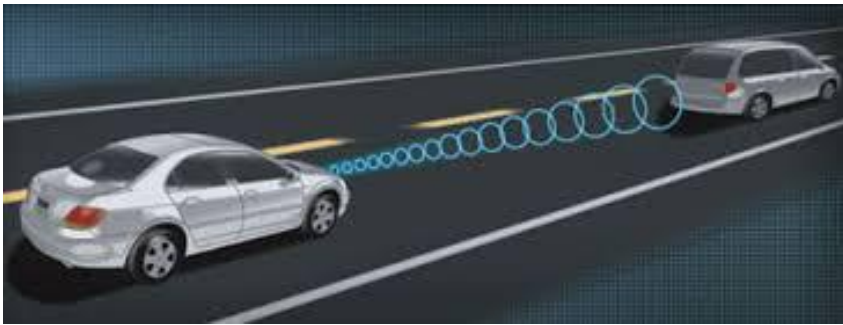
Unmanned systems and vehicles

- **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

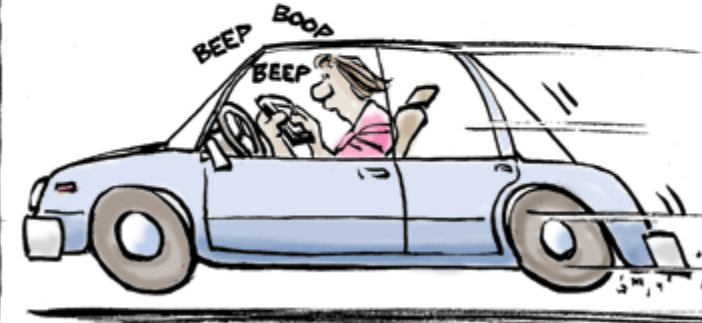


"Does your car have any idea why my car pulled it over?"

**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

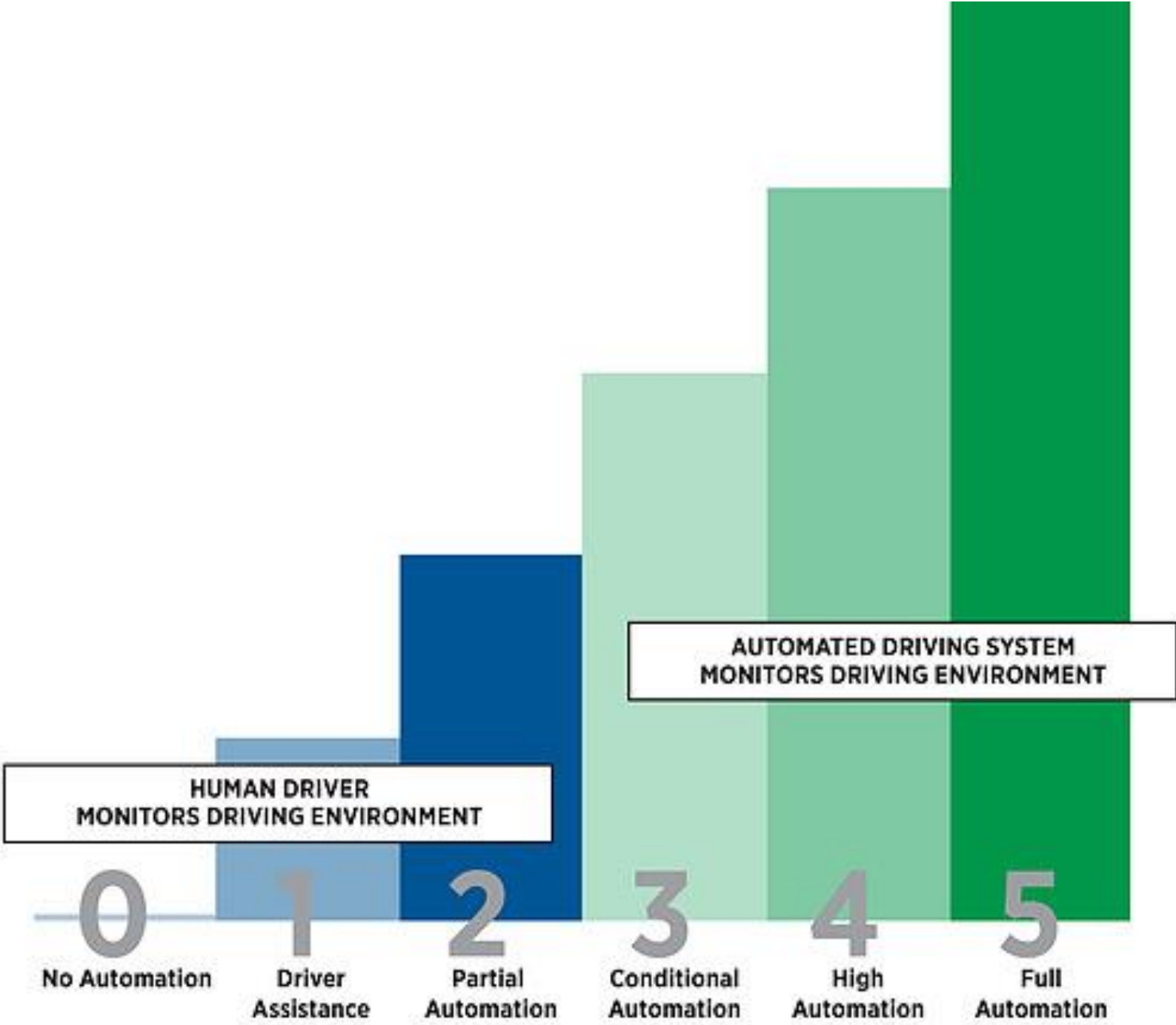
- **Standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (2014)**
 - Identifies six levels of driving automation from “no automation” to “full automation”
 - Describes categorical distinctions for a step-wise progression through the levels
 - Eliminates 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>)
Human driver monitors the driving environment						
0	No Automation	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
1	Driver Assistance	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
2	Partial Automation	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>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	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	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system 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	System	Some driving modes
5	Full Automation	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	All driving modes

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

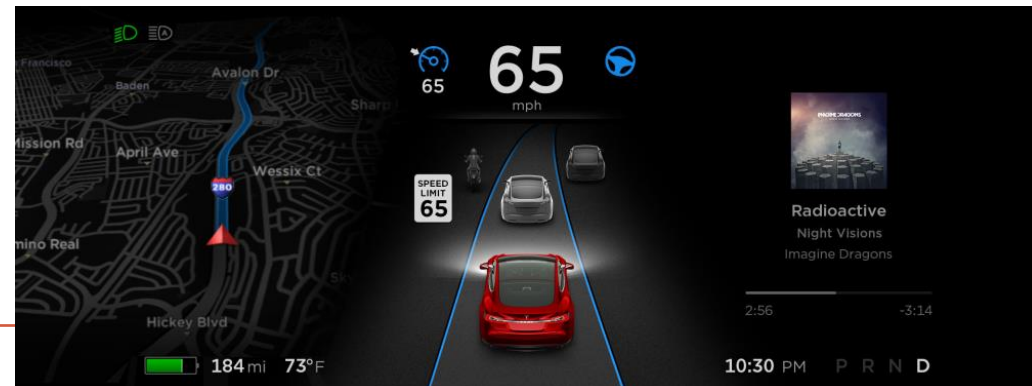
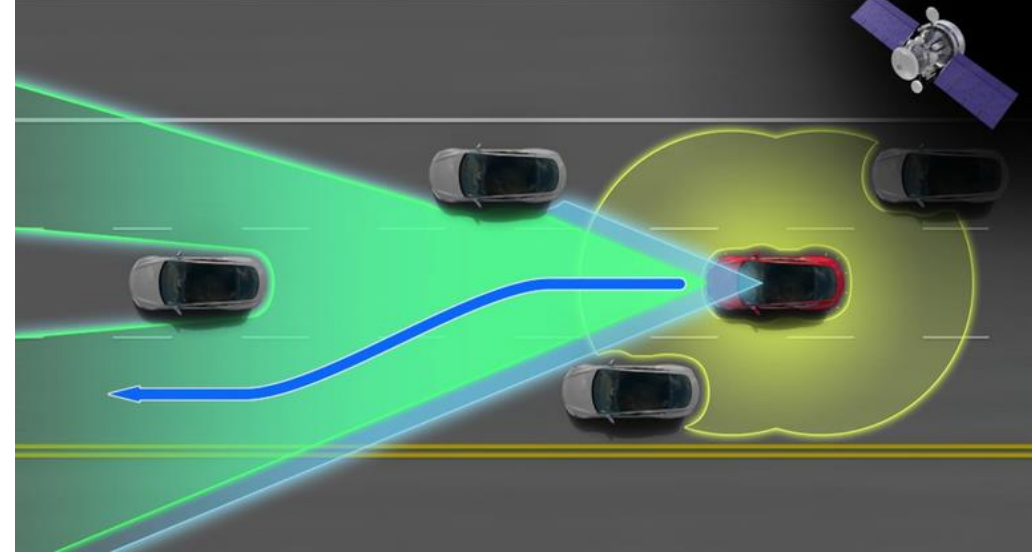
History of automated cars

- 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



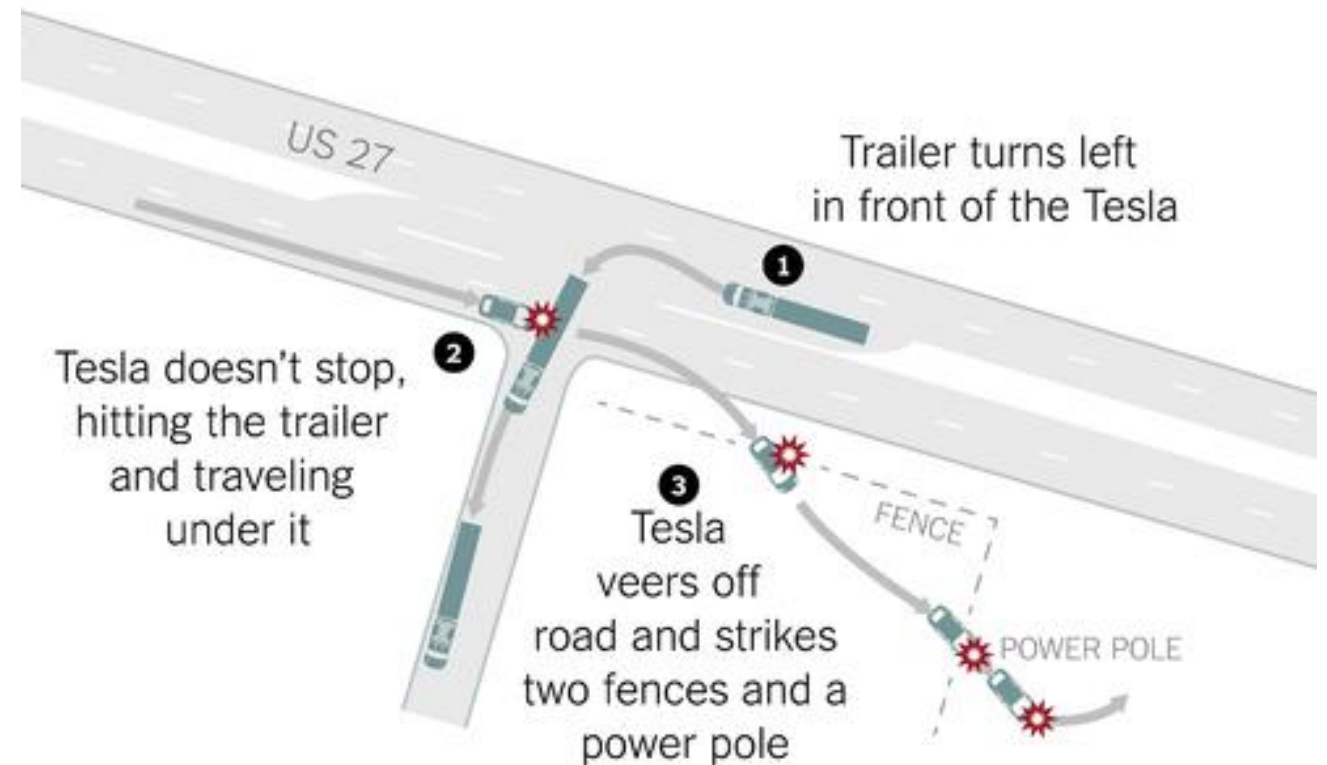
Tesla Autopilot

- 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



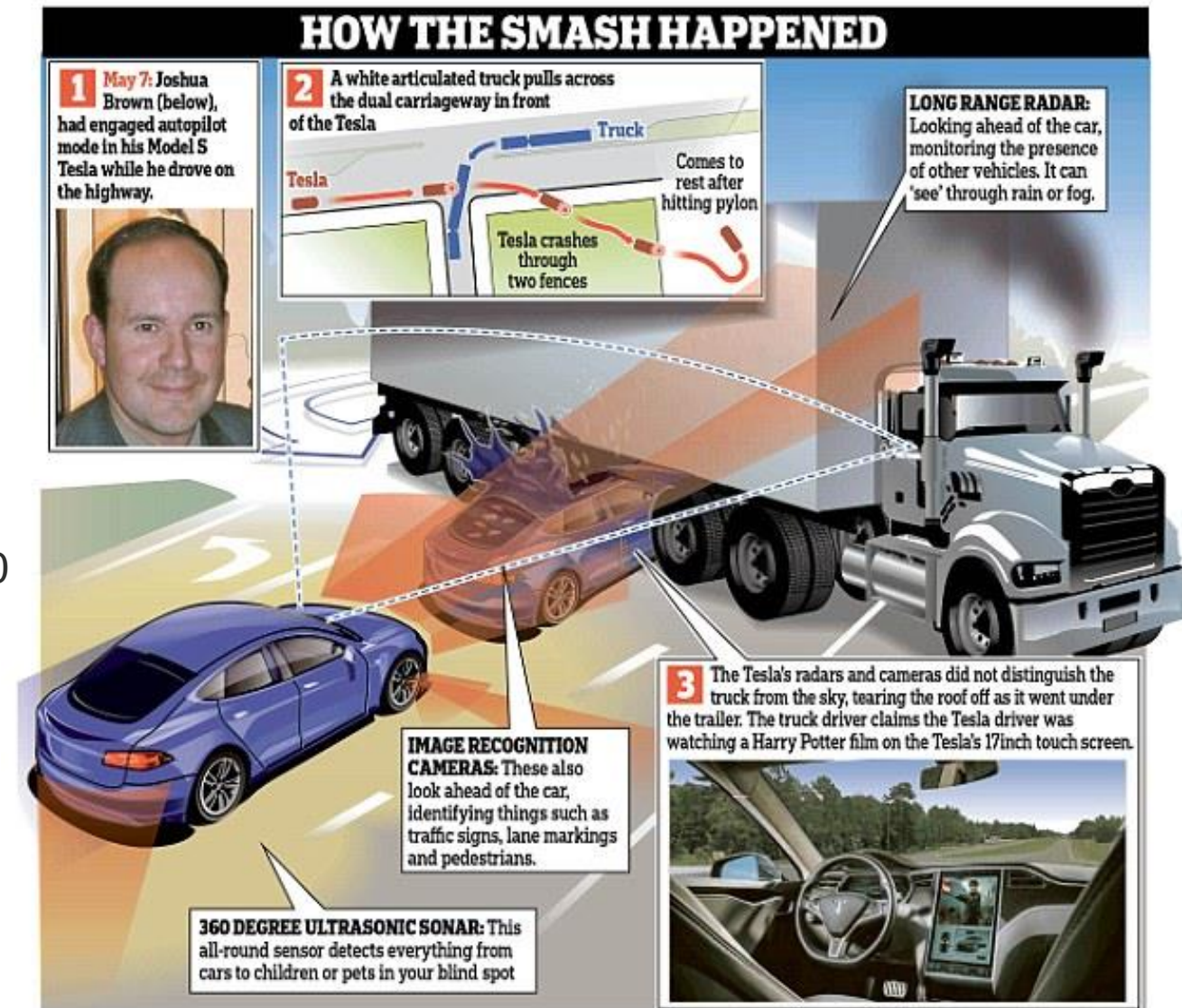
First fatality with Tesla Autopilot

- 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?

