Automated driving
Intelligent Transportation Systems

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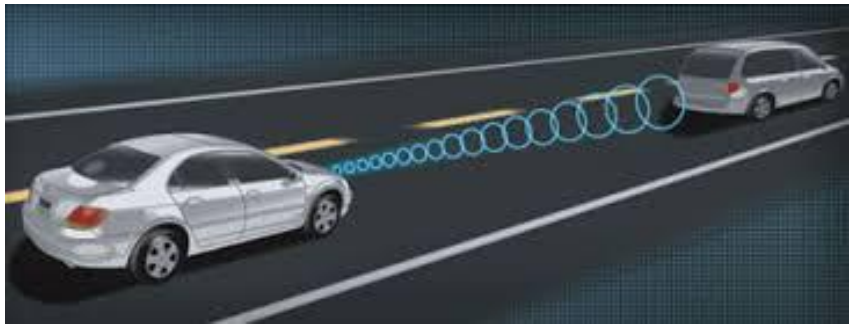
Unmanned systems and vehicles

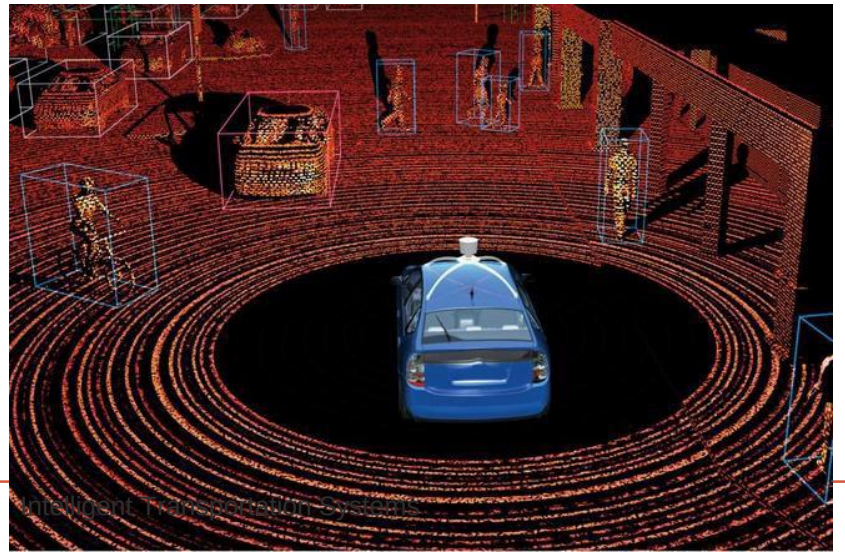
- **Unmanned system**: any electro-mechanical system which has the capability to carry out a prescribed task or portion of a prescribed task automatically, without human intervention
- **Unmanned vehicle**: a vehicle that does not contain a person
  - Can be tele-operated
  - Can be autonomous – takes decisions independently

- Unmanned vehicles can come in several flavors: **UxV**
  - Land: UGV (Unmanned Ground Vehicle)
  - Air: UAV (Unmanned Aerian Vehicle)
  - Maritime: UUV, USV (Unmanned Underwater / Surface Vehicle)

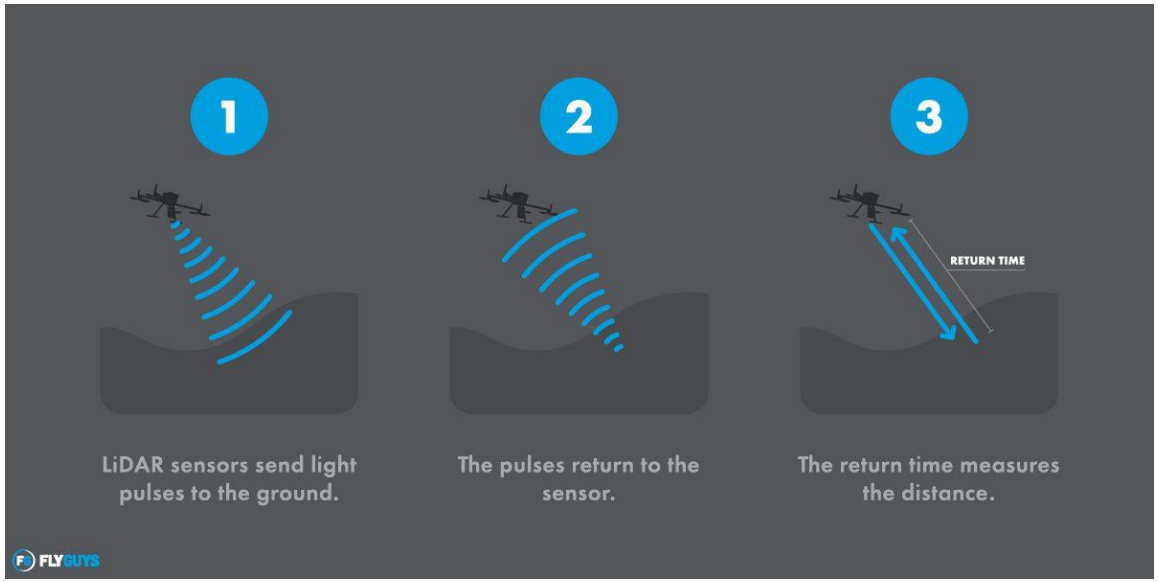
Autonomous / Self-driving cars

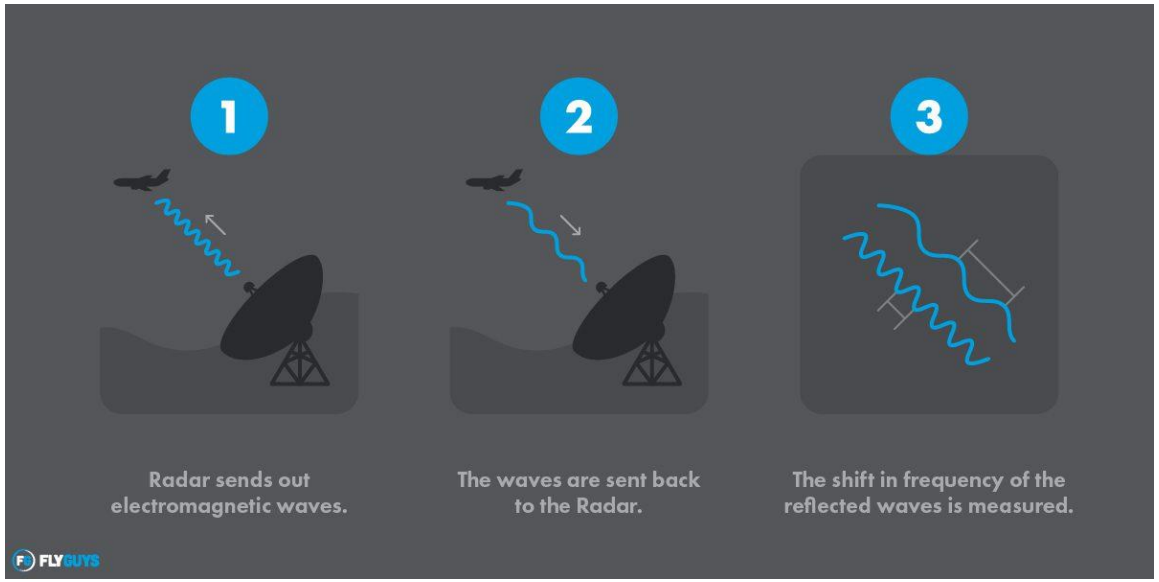
- A vehicle capable of sensing the environment, and navigating without human input
- Different techniques to detect their surroundings
  - **Radar** (RAdio Detection And Ranging) – radio waves to determine range, angle and velocity of objects
  - **Lidar** (LIght Detection And Ranging) – illuminating 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





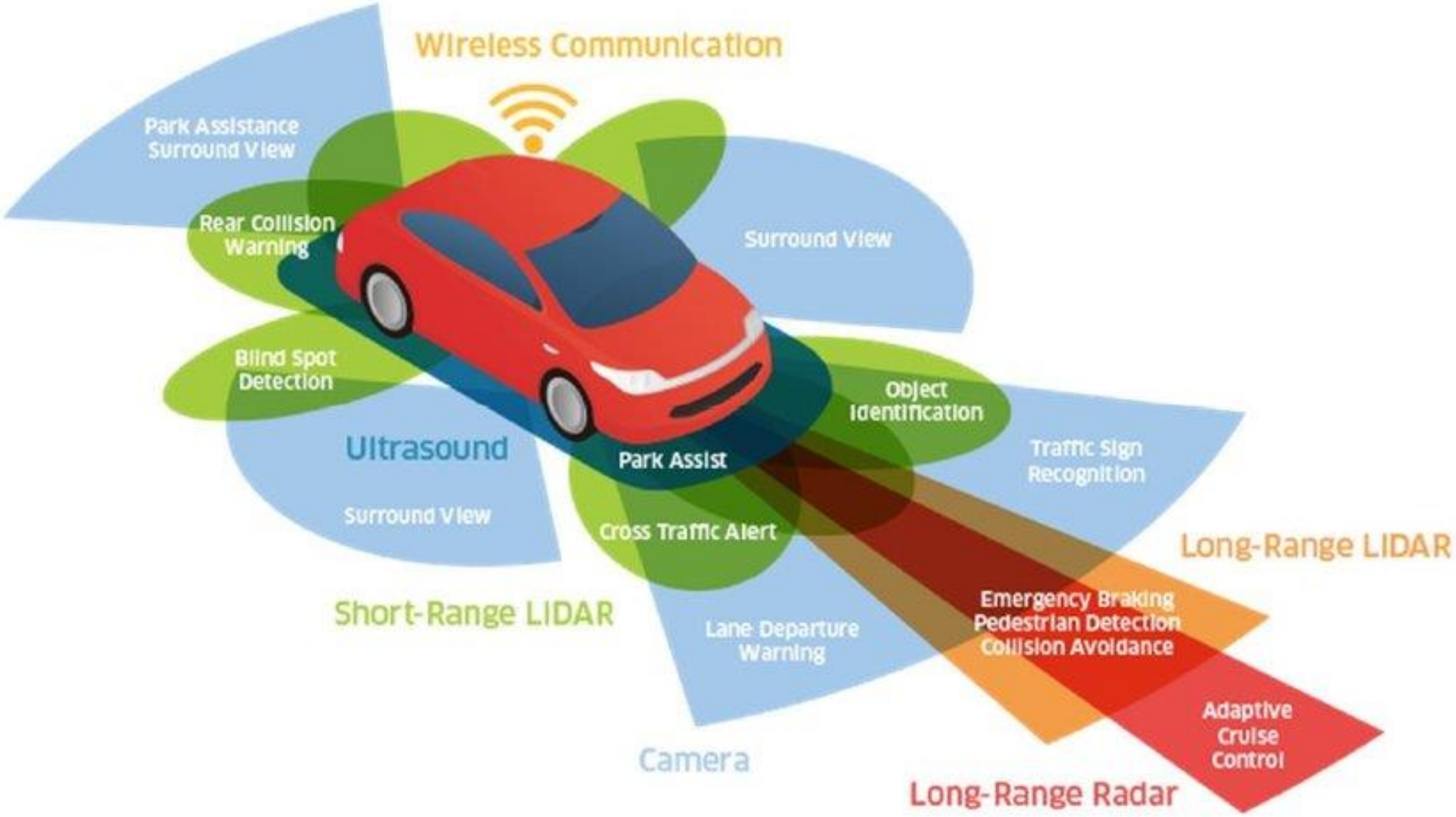
Radar vs. Lidar





- Lidar more precise in determining distance, but is more expensive and requires Line-of-Sight (LOS)
  - Used to build a 3D-map of the surrounding world
- Radar works for larger distances, less precise, but less expensive, works through fog, rain
  - Ued to detect and track objects

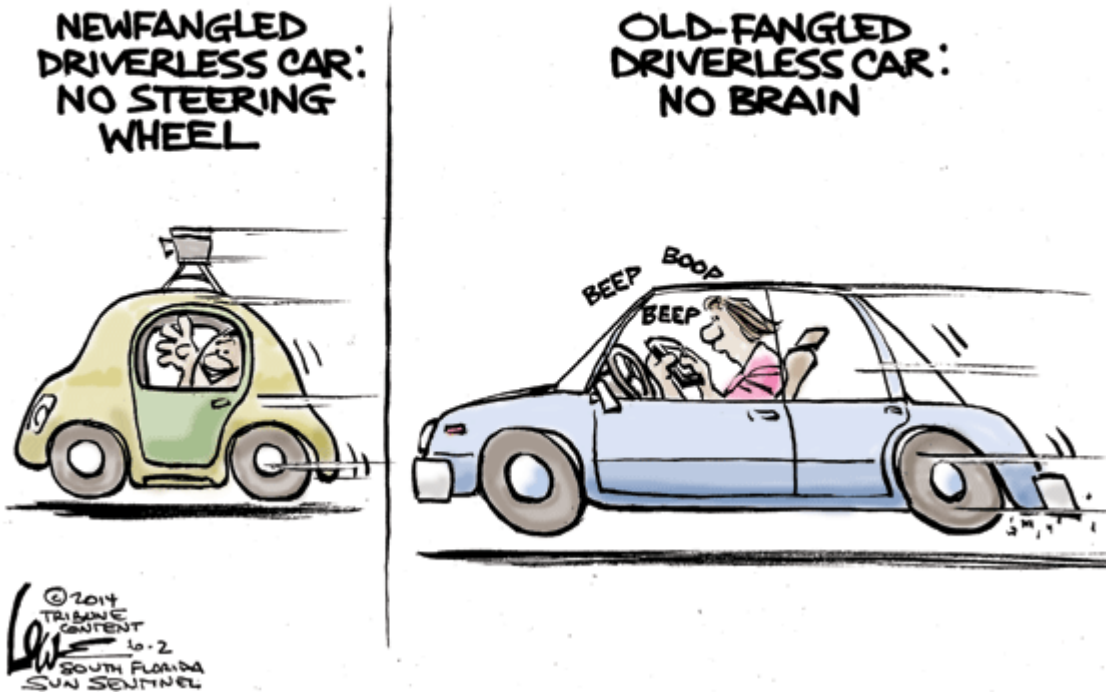
Radar vs. Lidar vs. Camera



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?"



What does automated driving mean?

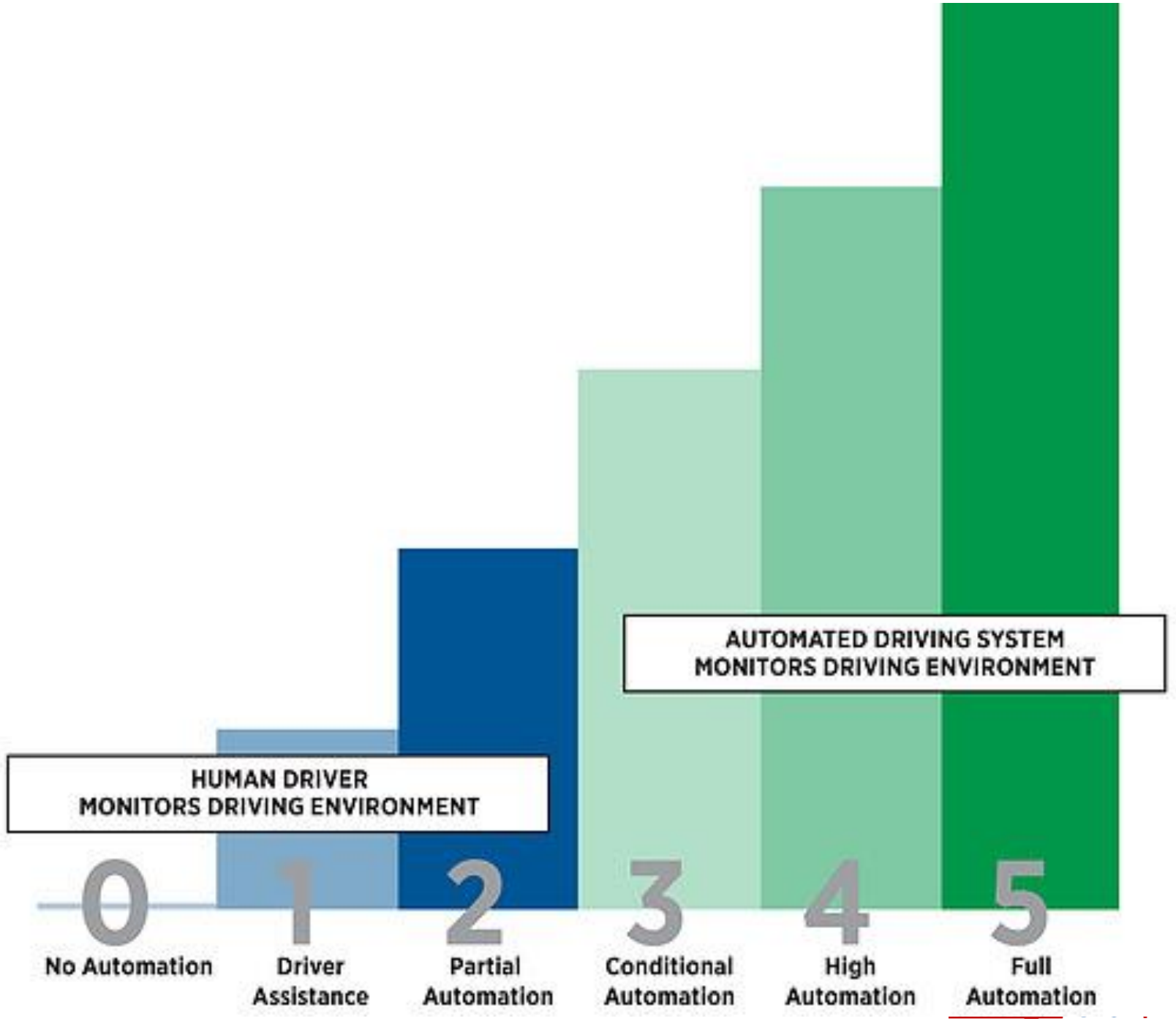
- **SAE International – Society of Automative Engineers**
  - Professional association and standards developing organization
  - Automotive, aerospace, and commercial vehicles
  - More than 138.000 individual members worldwide

- **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 *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-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 *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-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 *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Levels of automation

- **Level 0 (no automation)** – The human driver controls all (steering, brakes, throttle, power)
  - Only warnings form 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

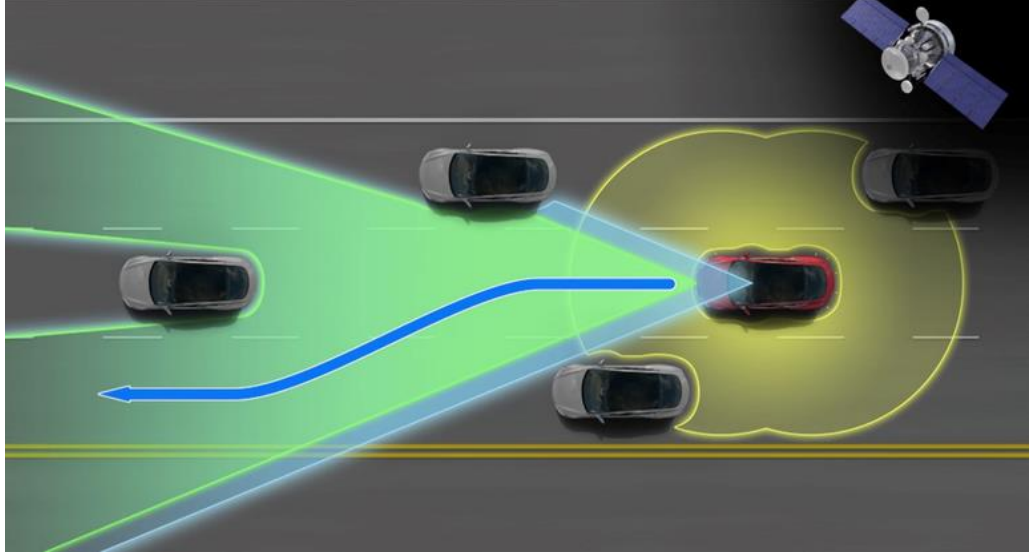
- **Level 4 (high automation)** – „mind off”
  - Vehicles perform all safety-critical driving functions, and monitor the roadway conditions
  - Driver may go to sleep, or leave the driving seat
  - It does not cover all driving scenarios, only limited areas (geofencing) or special conditions (traffic 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

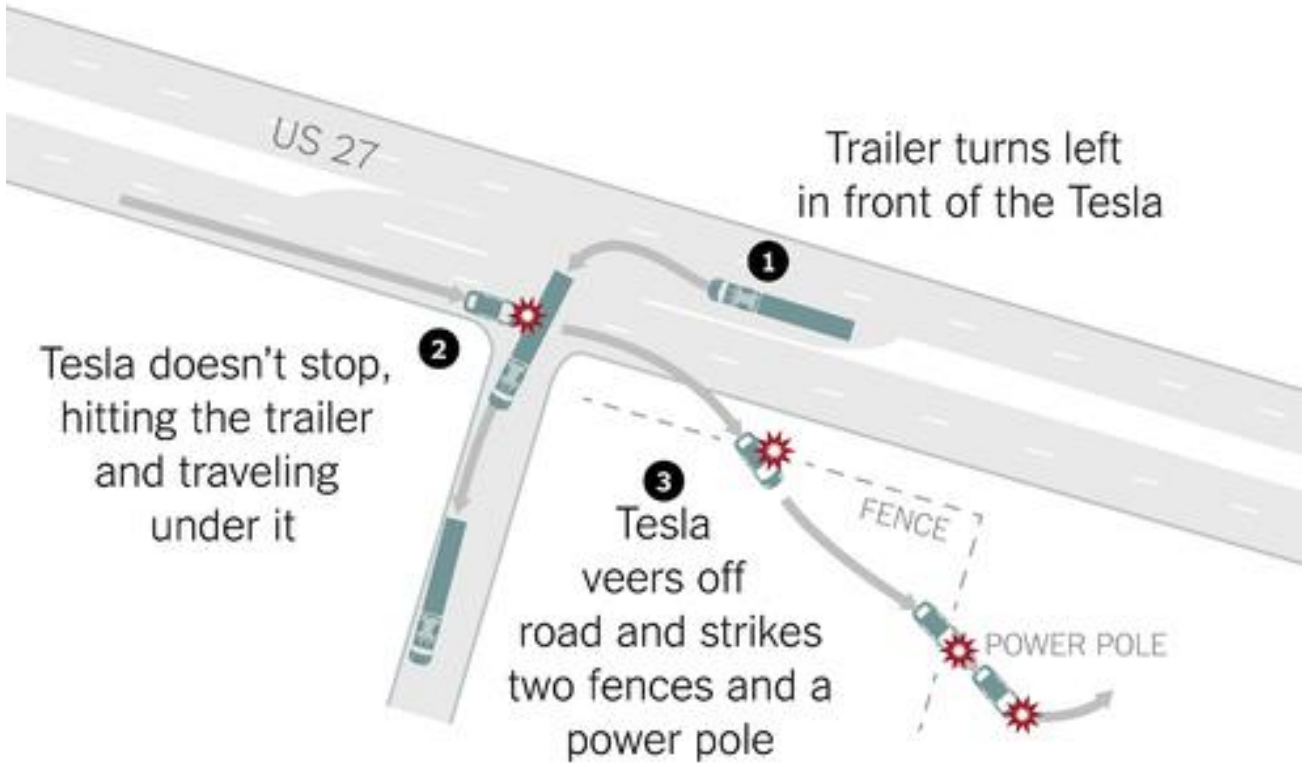


Tesla Autopilot

- 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

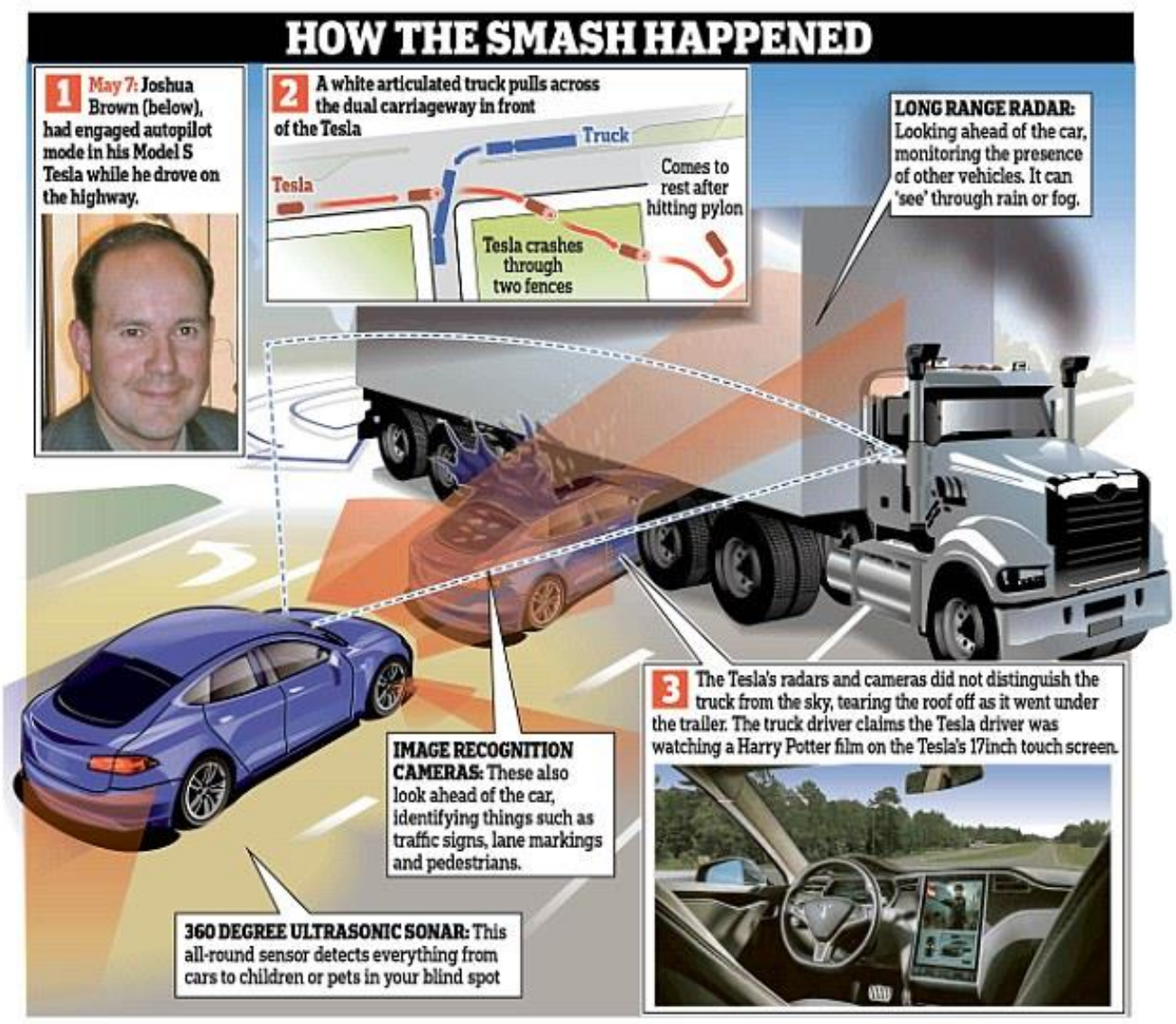
First fatality with Tesla Autopilot

- 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?