ON THE PATH TO AUTONOMOUS VEHICLES

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AGENDA

- Introduction and Definitions
- History
- Today
- Potential
- Autonomous Vehicle Programs
- Predictions and Conclusions

INTRODUCTION

VEHICULAR AUTOMATION

- ***Vehicular automation*** involves the use of
  - ✓ Mechatronics (Mechanics + Electronics)
  - ✓ Artificial Intelligence (AI)
  - ✓ Multi-agent System

  to assist a vehicle's operator *Automatic Driver Assist System*, or "*ADAS*".
- These vehicle features may be labeled as "*intelligent*" or "*smart*".
- A vehicle using automation for difficult tasks, especially navigation, may be referred to as "*semi-autonomous*".

DEFINITIONS

- An ***autonomous car*** is a type of ***autonomous vehicle*** capable of fulfilling the human transportation capabilities of a traditional car.

- An ***autonomous vehicle***, is capable of sensing its environment and ***navigating without direct human input (ie, truck, small delivery, paratransit, drones).***

HISTORY

TIMELINE

1890

- Electric cars invented (William Morrison) and commercialized as taxis

1920

Transmitting Antenna for radio

First 4-way three-color traffic control device, basis for the modern traffic signal (William Potts, a Detroit Traffic Police Superintendent)

1930

- Embedded circuits and radio controllers

1950

- Detector Circuits
- Special Radio Receivers
- Audible And Visual Warning Devices

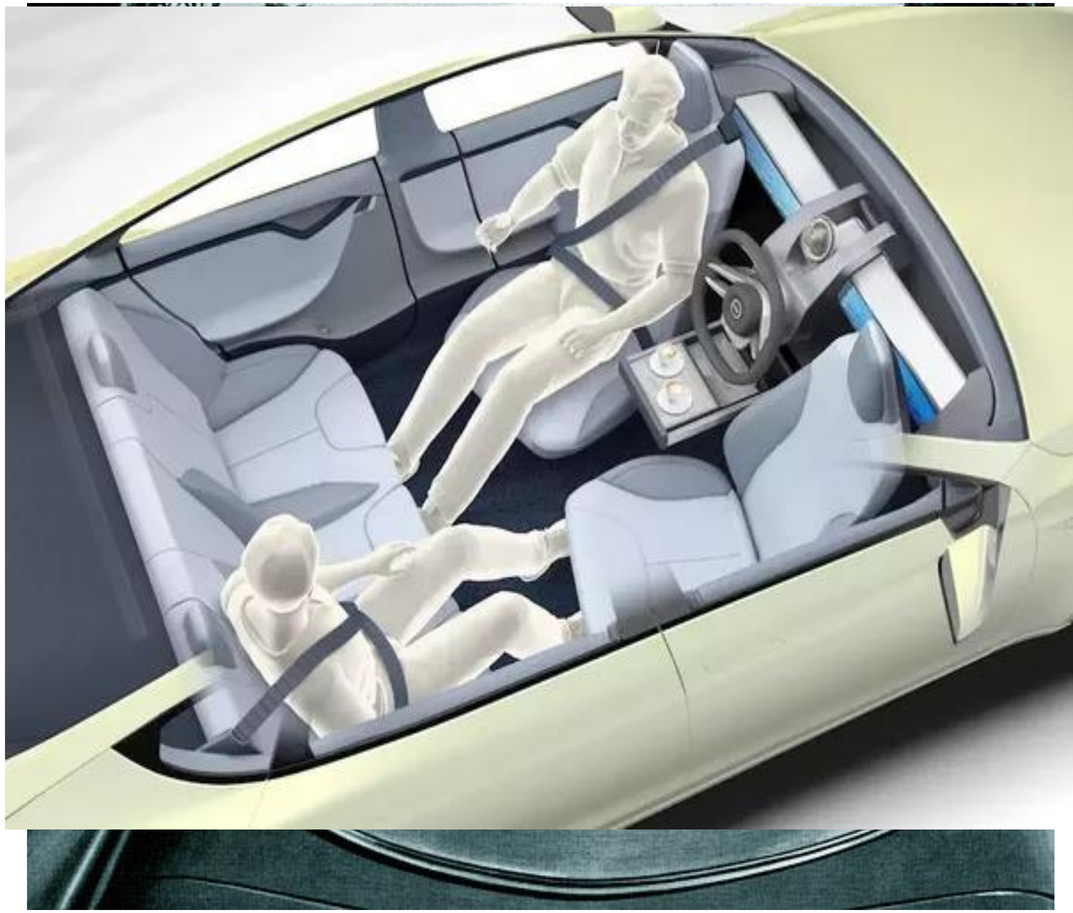
1960

- Electronically Controlled Highways
- Vehicles Powered And Controlled By Buried Cables or magnets
- Wayside Communicators Relaying Computer Messages

- First solid state digital intersection traffic controller
- GM engineers design the “Driver Aid, Information and Routing (DAIR), which relied on punch cards to provide information for basic turn-by-turn direction

EARLY PREDICTIONS

- Inspired by the efforts of an **electric utility company**, Central Power and Light Company, launched an advertorial that was posted in many leading newspapers throughout ***1956*** and ***1957*** and ***predicted the arrival of autonomous cars***:
- *ELECTRICITY MAY BE THE DRIVER.*

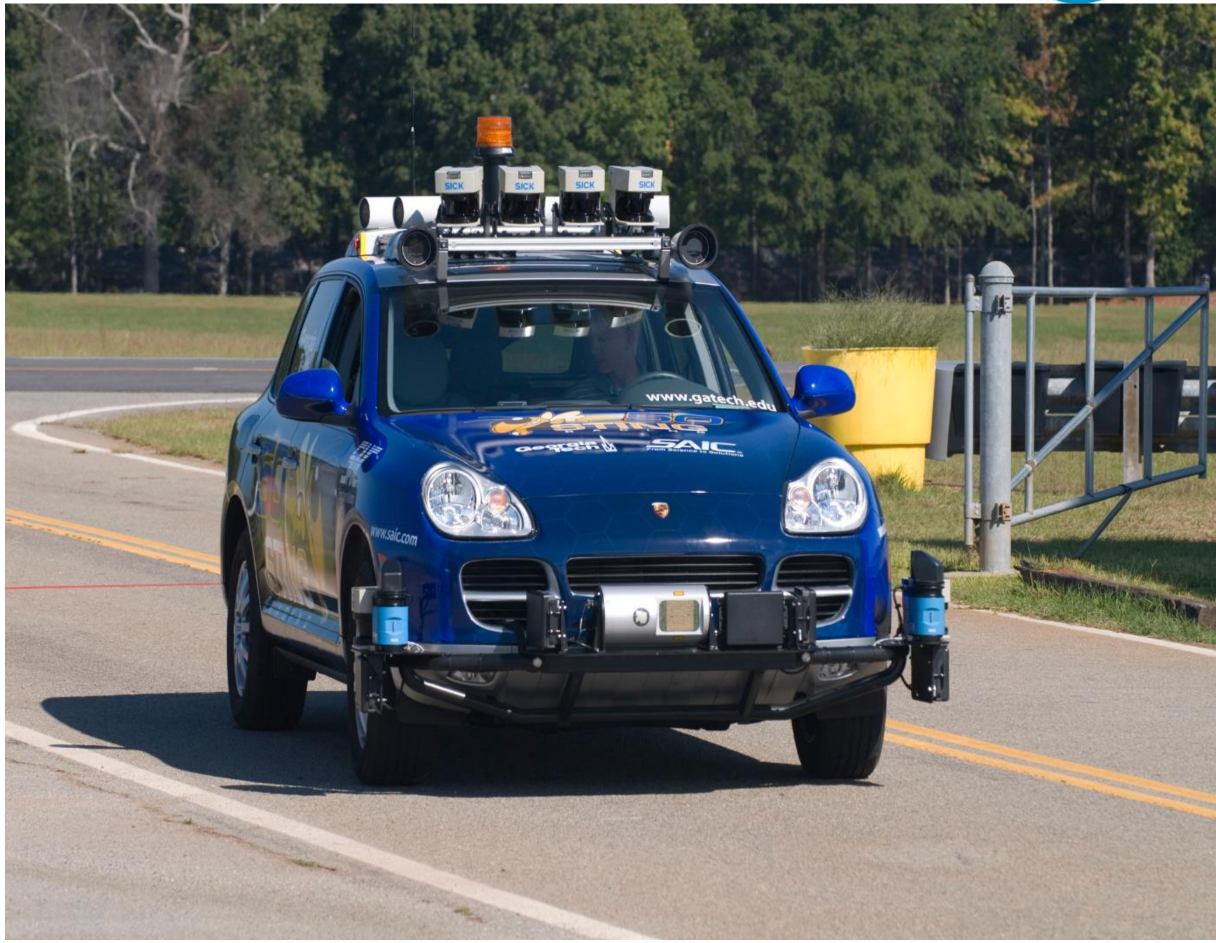


TIMELINE

1970	1980	1990	2000	2010
First microprocessor-based intersection traffic controller	• Laser radar, computer vision and autonomous robotic control • Off-road map and sensor-based autonomous navigation	• Extensive systems engineering work and research • First commercial sale of a video-based vehicle detection system • Onboard video cameras and use of stereoscopic vision algorithms • RFID-tags used for tolling, access control and infrastructure security • Introduction of fully adaptive traffic management systems	• Real-Time Control System • First commercial sale of a video vehicle tracking-based detection system	• Artificial Intelligence (AI) released for commercial use • GPS, LIDAR, 3D mapping, cameras, advanced sensors, etc.

2007- FIRST AUTONOMOUS VEHICLES

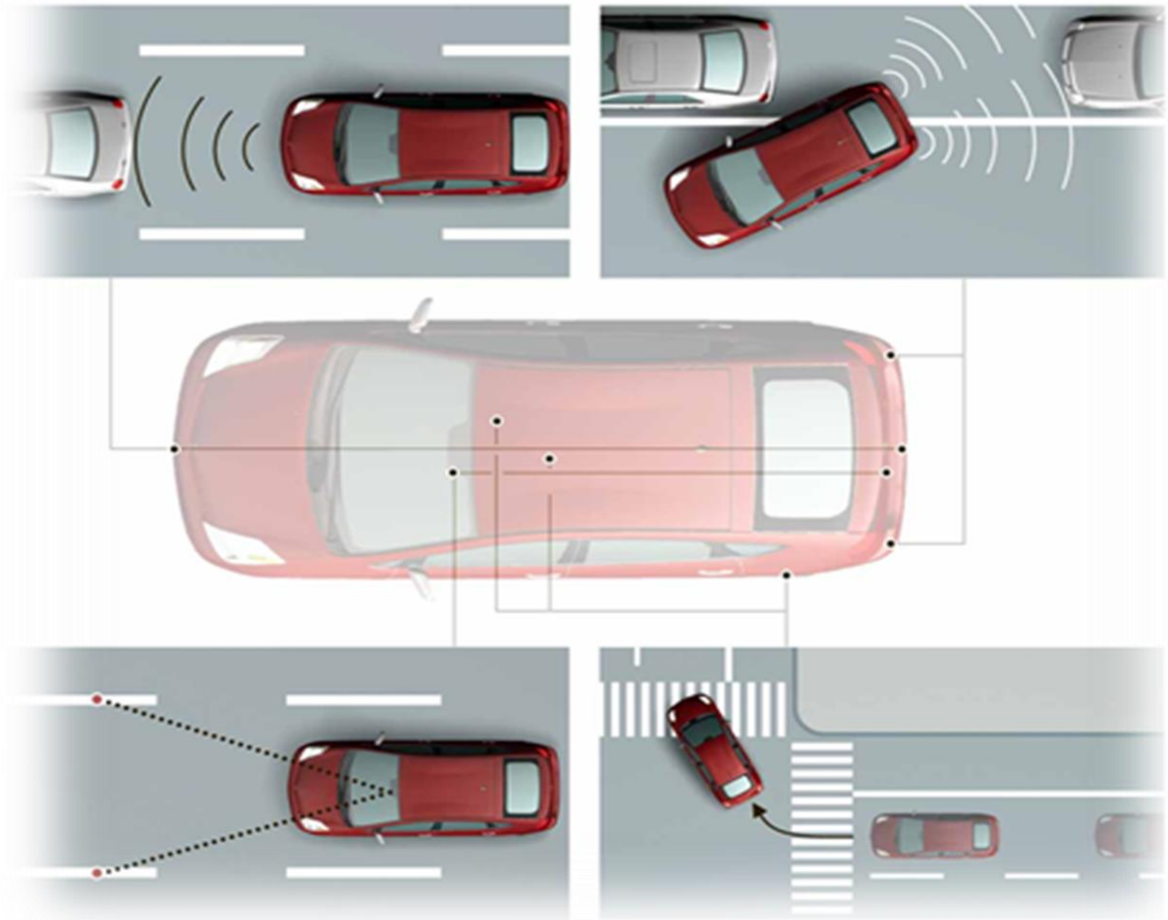
- **Stage 1** → Porsche Cayenne. This autonomous vehicle was designed by the **Georgia Institute of Technology** in collaboration with Science Applications International Corporation (SAIC) for the **Defense Advanced Research Projects Agency's (DARPA) Urban Challenge in 2007.**



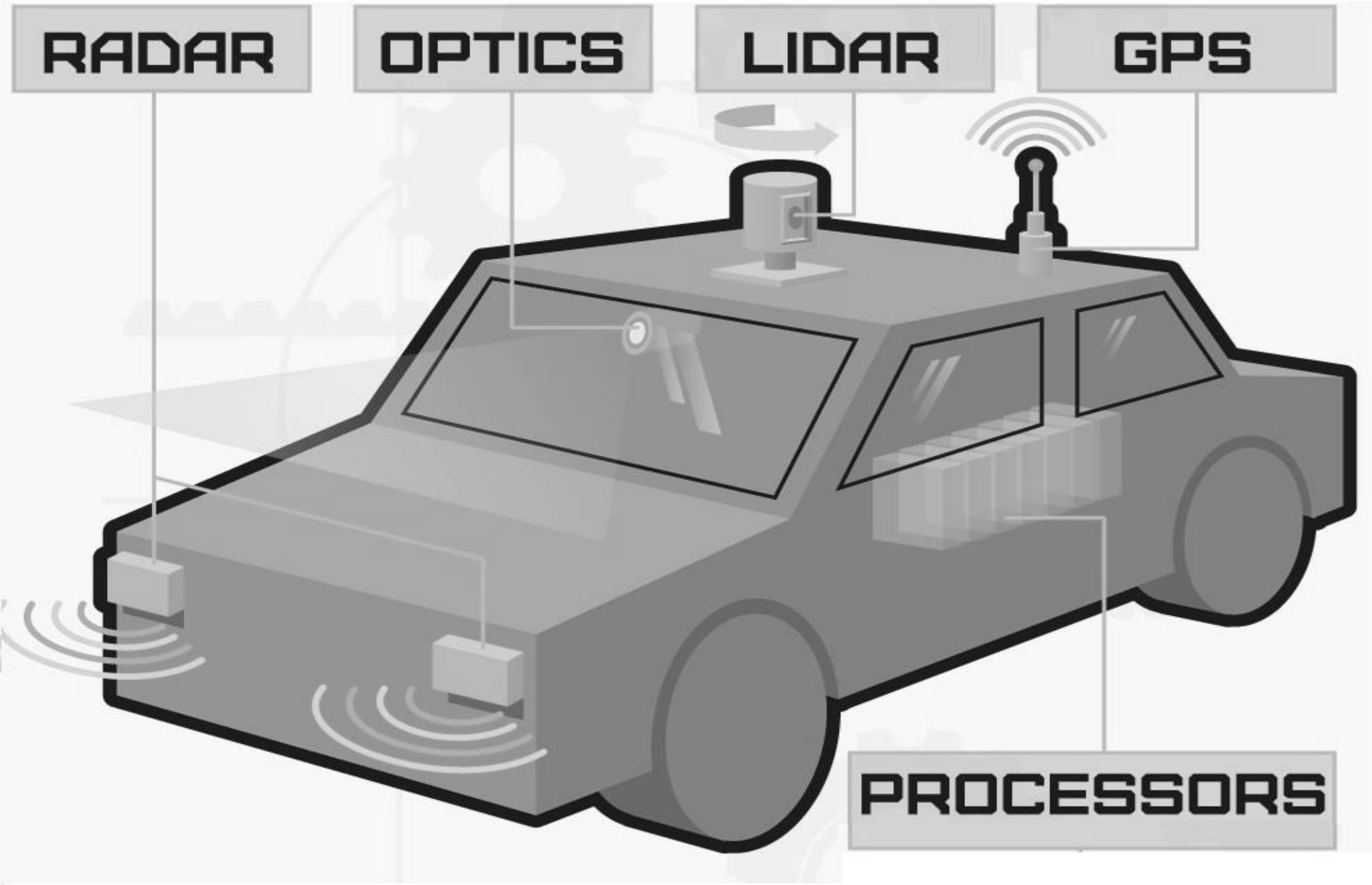
TODAY

VEHICLE HARDWARE

- RADAR
- Optics
- LIDAR
- GPS
- Processors
- Wheel Speed Sensors

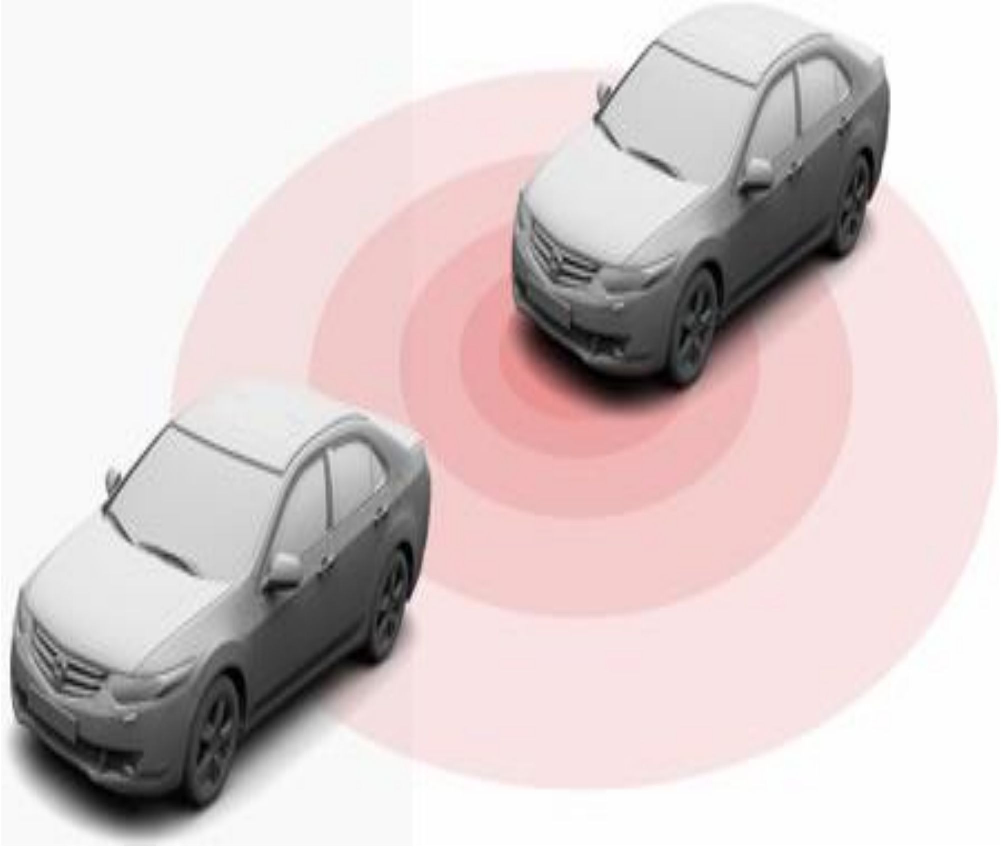


LOCATION, SURROUNDINGS, HAZARDS, OTHER VEHICLES



RADAR - RADIO DETECTION & AND RANGING

- Traditional **RADAR** sensors are used to detect dangerous objects in the vehicle's path that are **more than 100 meters away.**
- Accident-Prevention Systems (APS) trigger alerts when they detect something in a blind car's blind spot.
- The radar chirps between 10 and 11 GHz over a 5 millisecond period, transmitting the radar signal from a centrally located antenna cone.
- Two cone receivers, separated by approximately 14 inches, receive the reflected radar energy.

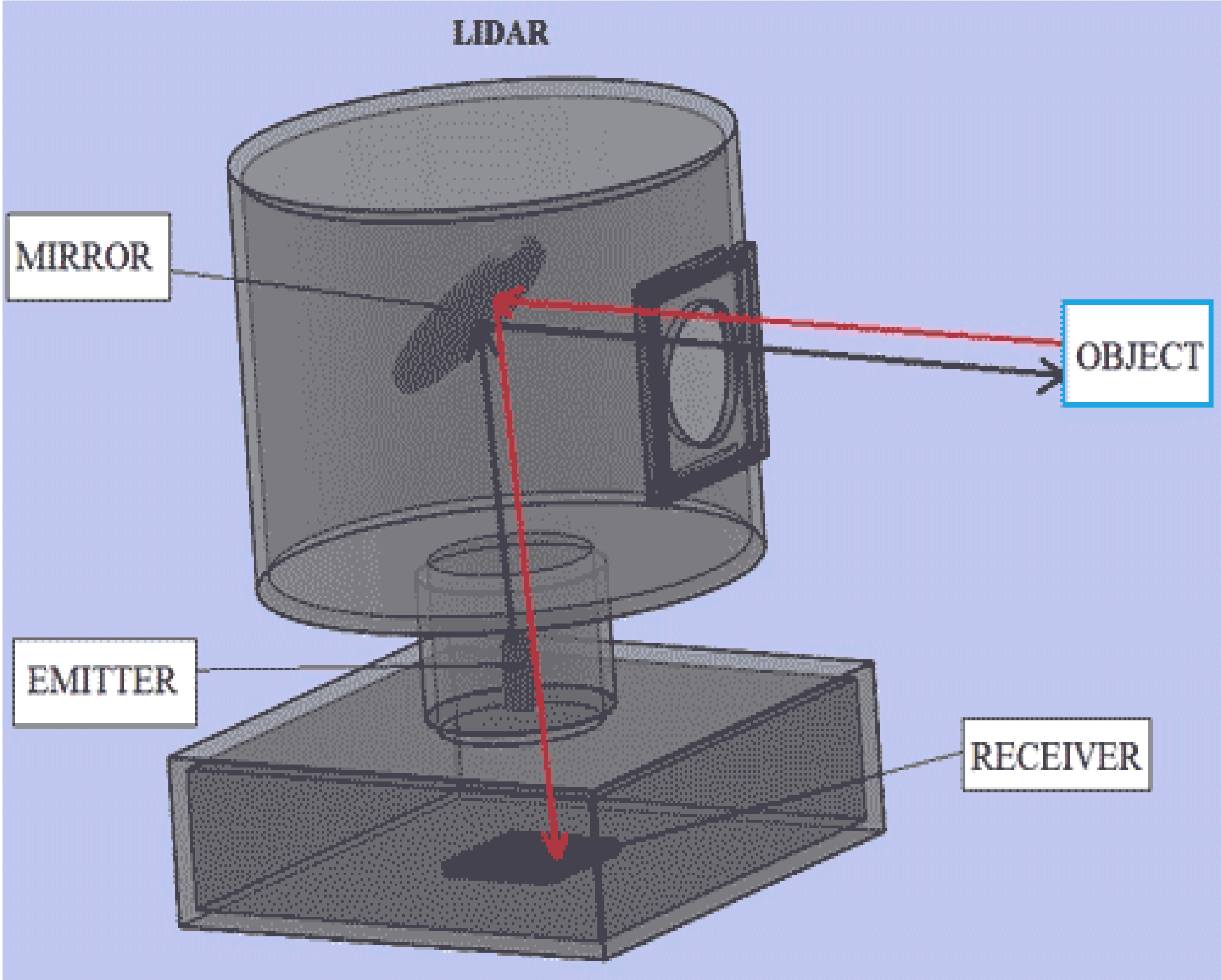


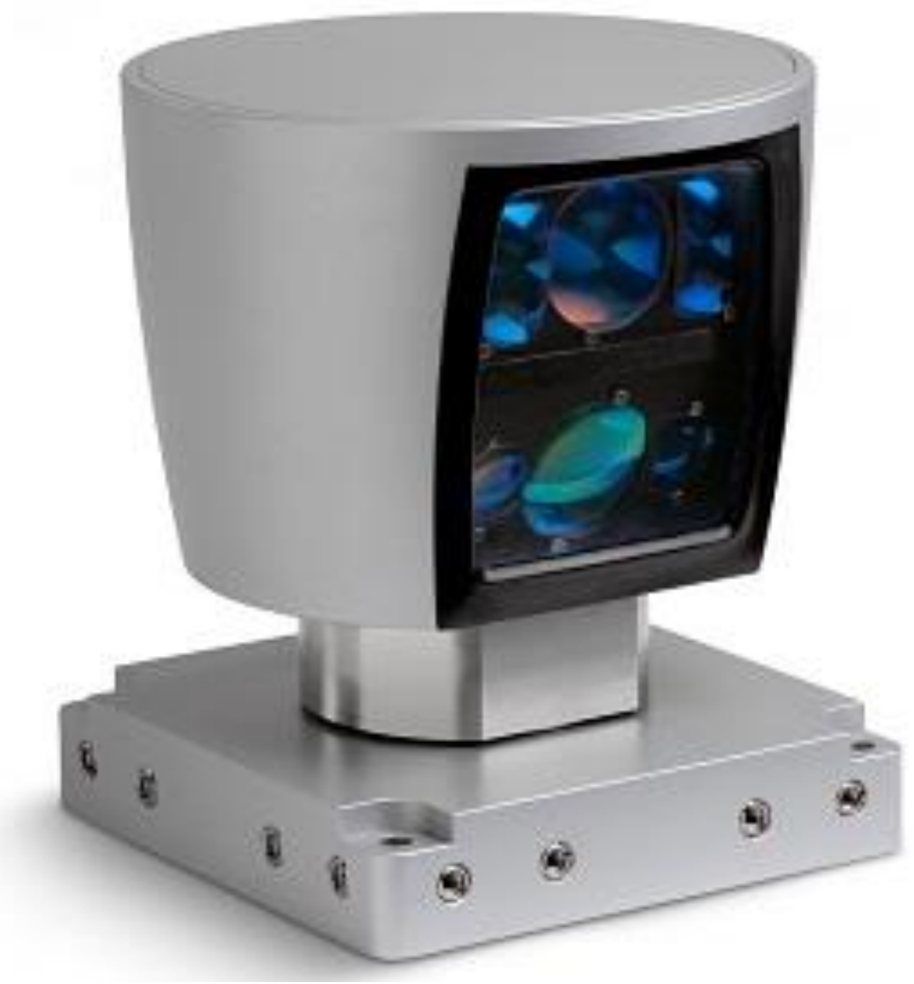
OPTICS

- A camera mounted near the rear-view mirror build a **real-time 3D image** of the road ahead, spotting hazards like pedestrians and animals.

- It is also used to identify road markings and traffic signals.

LIDAR





GPS

- A ***Global Positioning System (GPS)*** keeps the car on its intended route with an ***accuracy of 3-4 meters. (Versus desired accuracy of 30 centimeters)***
- With GPS covering the macro location of car, smaller on-deck cameras can recognize smaller details like red lights, stop signs and construction zones.

NAVIGATION SYSTEMS

- In-dash navigation today:
  - ➢Pros: seamless integration with vehicle.
  - ➢Cons: Expensive; limited data and performance; inferior to smart phone apps like Waze, Google Maps.
- Smart Phone apps:
  - ➢Pros: no additional expense needed; superior performance to in-dash.
  - ➢Cons: small screen size; not integrated, harness needed.

PROCESSORS

- Some seven (7) dual-core 2.13 GHz processors and 2GB of RAM are needed to make sense of the data collected by the car’s instruments.

- Some cars run as many as 17 processors to share the computing load.

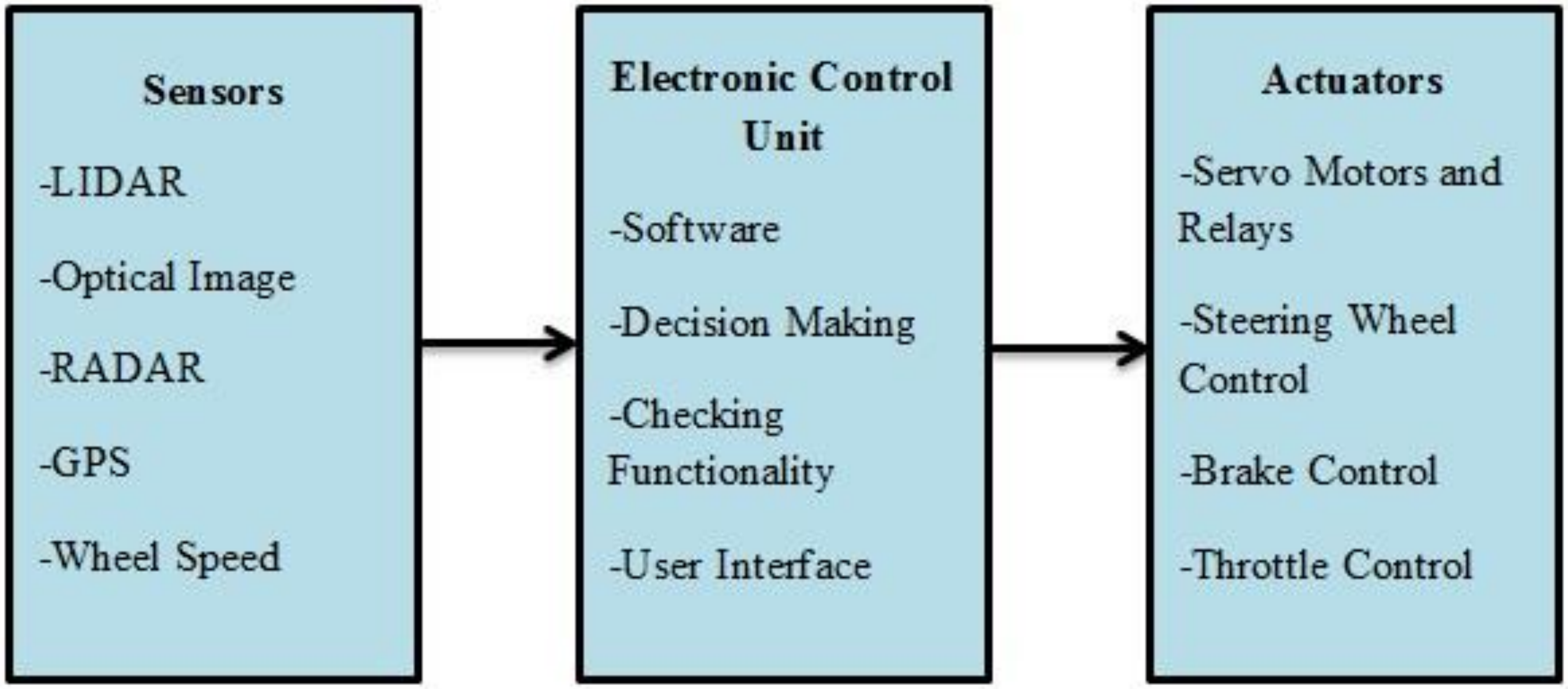
WHEEL SPEED SENSORS

- ***Wheel Speed Sensors*** measure the road-wheel speed and direction of rotation.
- These sensors provide input to a number of different automotive systems including the ***anti-lock brake system and electronic stability control.***

WORKING

- The signal from the sensors are used by the ***On-Board Unit (OBU) & Electronic Control Unit (ECU)*** for decision-making using a software code.
- Based on the information from the sensors, the Electronic Control Unit gives signal to the actuators, which in turn control the vehicle.
- Also, real time information of the surroundings is output to the user interface located inside the vehicle.

AUTONOMOUS VEHICLE OPERATION



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POTENTIAL

BENEFITS, CHALLENGES AND OBSTACLES

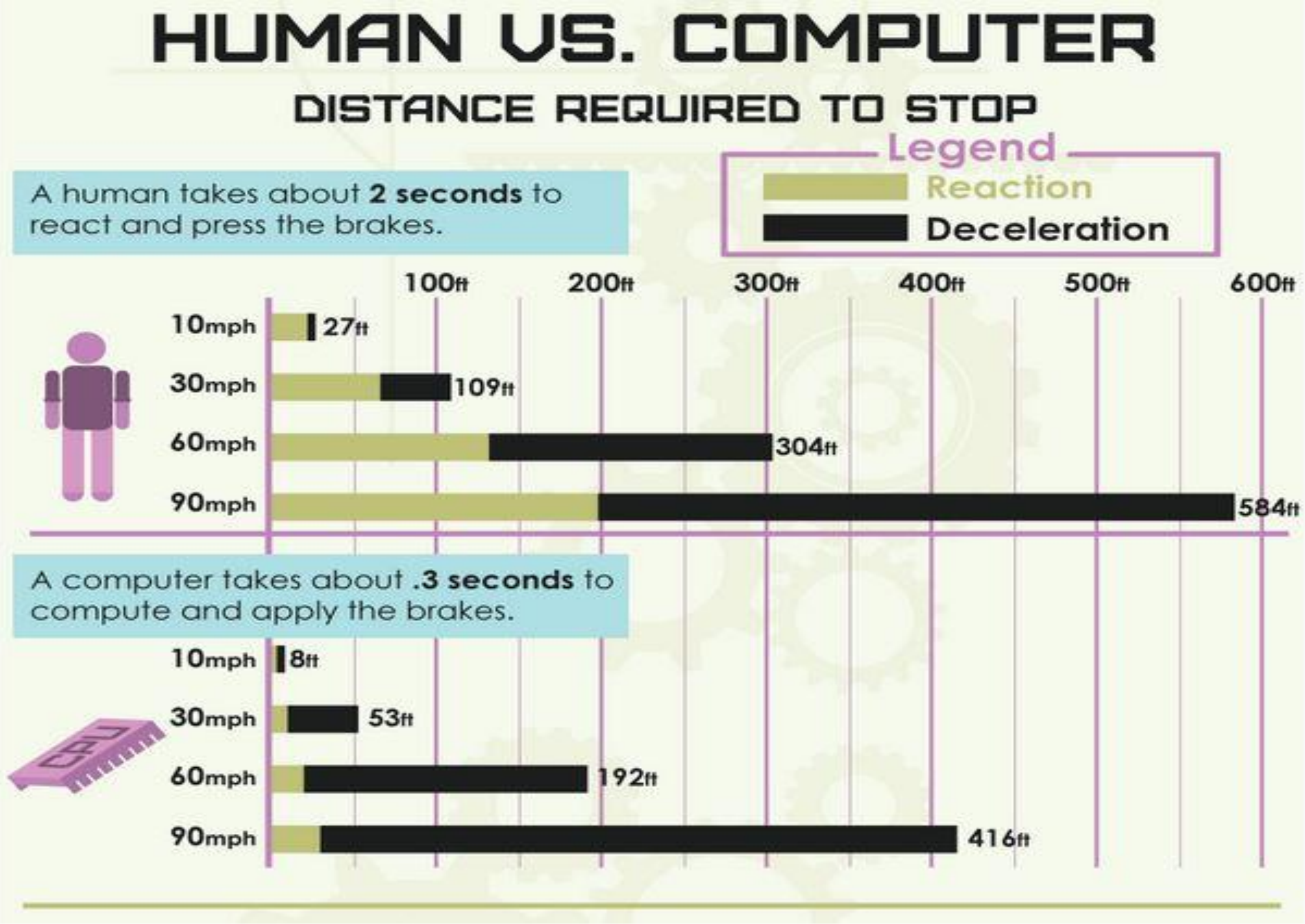
FUTURE NAVIGATION

- With the arrival of connected vehicles, in-dash navigation systems will become far more powerful as they will be updated in real time by the overall fleet – routing, traffic conditions, and road pavement conditions – even the location of a new pothole!
- In-dash will be complimented by phone app for additional functionality (one account, data transfer)
- Example: HERE next generation navigation in-dash and app, was released in 2019 which learns from driver preferences and make informed suggestions for routing.

BENEFITS

- Safety:
  - Gradually fewer traffic collisions and injury accidents (as technology is deployed and gains acceptance)
  - Improved response time of first responders to accidents- police, fire, paramedics
  - Ultimately: the realization of “***Vision Zero***”- No more roadway fatalities or serious injury accidents
- Efficiency:
  - Lower speed limit with decreased gap and headway for autonomous cars…leading to…
  - ….Increased roadway capacity and reduced traffic congestion
  - Alleviation of parking scarcity- integrated parking guidance systems
  - Reduction of physical road signage- move toward “in vehicle” signage
  - Smoother ride with decreased stops
- Human Factors:
  - Relief of vehicle occupants from driving and navigation chores
  - Removal of constraints on occupants' state of mentation/impairment
- Government and Regulatory:
  - Reduction in the need for traffic police and vehicle insurance premiums

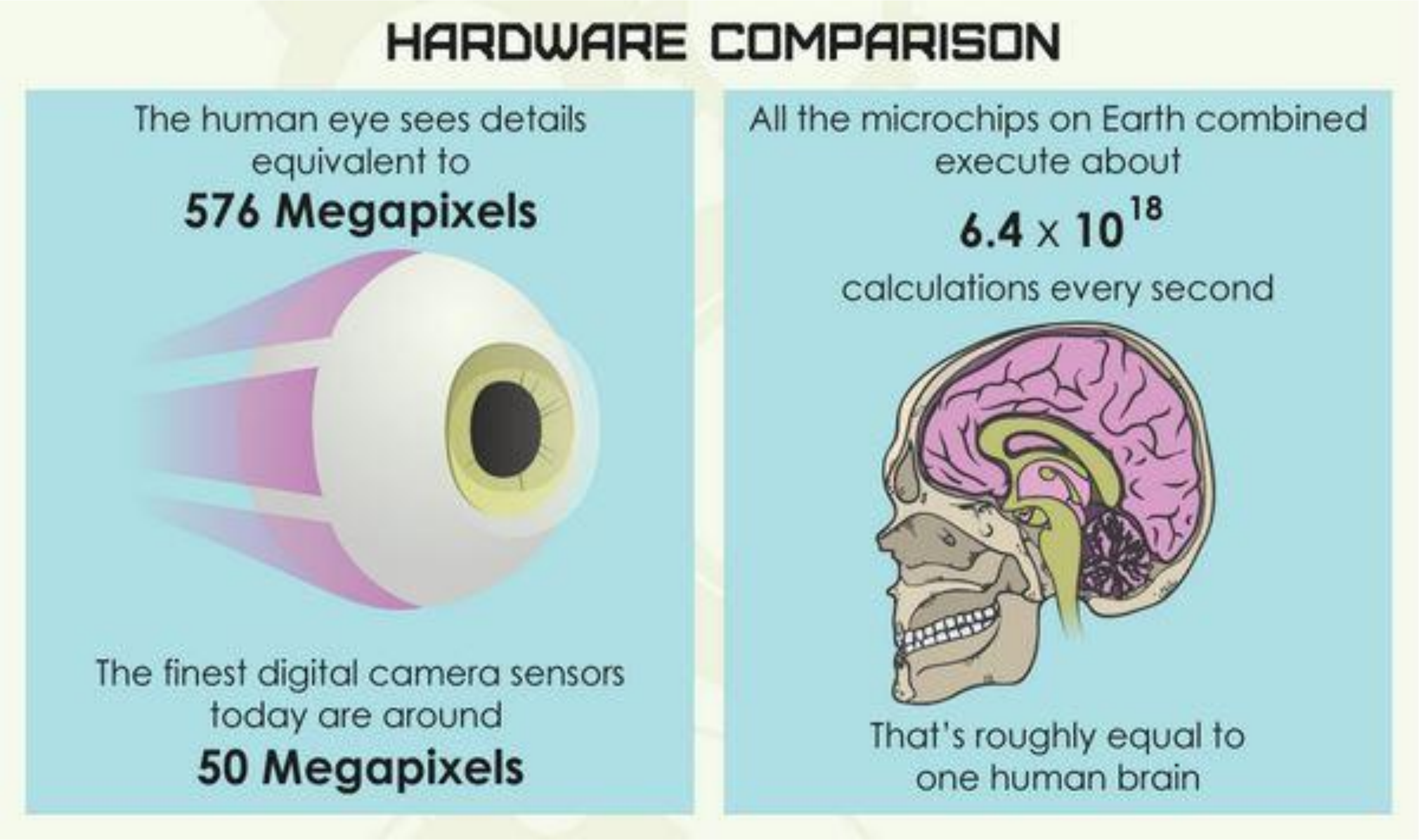
ELIMINATION OF "DILEMMA ZONE"



OBSTACLES AND CHALLENGES

- Safety (Technology and Legal)
  - ➢ Liability for damages due to vehicle systems malfunction (who pays?)
  - ➢ New custom chips will have to be developed for true AI for autonomy, needing far more reliability, accuracy and redundancy *
  - ➢ New software will have to be developed with far greater power, reliability, accuracy and redundancy **
  - ➢ Autonomous cars relying on lane markings cannot decipher faded, missing, or incorrect lane markings – significant attention will be required on all roadways
  - ➢ Temporary construction / work zones which are not posted to any maps or databases
  - ➢ Determination of the severity of traffic lane obstacles, as in the question of safely straddling a pothole or roadway debris ***
  - ➢ What about pedestrians and bicyclists? Will they require smartphones or DSRC transponders?

HUMAN VS. MACHINE VISION



OBSTACLES AND CHALLENGES (2)

- Human factors:
  - Resistance for individuals to forfeit control of their cars to machines *
  - Reliance on autonomous drive produces less experienced drivers when manual control is needed, such as in work/construction zones **
- Security:
  - Cybersecurity - Electronic security of in-vehicle systems, roadside systems and control network
  - Terrorism - Potential misuse by bad actors (car bombs)

OBSTACLES AND CHALLENGES (3)

- Government and Regulatory:
  - Implementation of legal framework and establishment of a comprehensive government-led, consensus-based regulatory framework for self-driving cars *
  - Lack of government funding to upgrade existing, and install new intersection equipment with Roadside Units (RSU) to receive wireless data via DSRC/5G/C-V2I from all connected vehicles
  - All solutions must be multi-modal in nature and include Class 1 rail, light rail, bus, ride sharing, autonomous taxis, etc.
- Privacy:
  - Continued loss of personal privacy/ personal movement can be easily monitored

AUTONOMOUS VEHICLE PROGRAMS

1. Short to Mid-term Applications
2. Mid to Long-Term Applications
3. Long-Term Applications

1. SHORT TO MID-TERM APPLICATIONS/DEPLOYMENTS

AUTONOMOUS DELIVERY VEHICLES

Nuro's prototype self-driving vehicle is about half the width of a standard sedan. Tests by end 2018.

AUTONOMOUS DELIVERY VEHICLES (2)

Udelv, a competitor, is demonstrating its delivery vehicle, ferrying groceries from a store in Silicon Valley to two customers.

AUTONOMOUS DELIVERY VEHICLES (3)

EasyMile, another competitor, demonstrating autonomous baggage tractor for airport use

BENEFITS

- Ideal for e-commerce growth.
- So called "first mile, last mile" applications. Door-to-Door mobility is needed.
- Ideal for high density urban areas and night time delivery (quiet).
- Delivery object does not have to drive smoothly, something that has been hard for autonomous cars.
- Regulatory approval easier: the AI doesn't have to make the complicated decision of [whether to] protect the passengers or the pedestrians because there are no passengers.
- More room for error - smaller than ordinary cars.
- Unlike other delivery robot start-ups, which design machines to travel at low speeds on pavements alongside pedestrians, these new vehicles will drive on the road and follow the same rules as regular traffic.

2. MID TO LONG-TERM APPLICATIONS/DEPLOYMENTS

PUBLIC TRANSPORT

Para-transit (small buses) is an immediate and obvious application.

- Immediate and significant benefits (lives saved, accident costs, labor costs).
- Low-speed, fixed routing in residential areas and business areas (feeding travelers to bus and subway stations).
- Successful tests around the world, U.S. examples:
  - **Transdev** in Florida, USA (with **EasyMile**)
  - **First Transit** in Northern California (with **EasyMile**)

TRUCK PLATOONING

- Platooning is one of the most effective ways to optimize logistics, transport flows and systems.
- Not full autonomy – lead vehicle driver present (faster regulatory approval)

3. LONG-TERM APPLICATIONS

AURORA

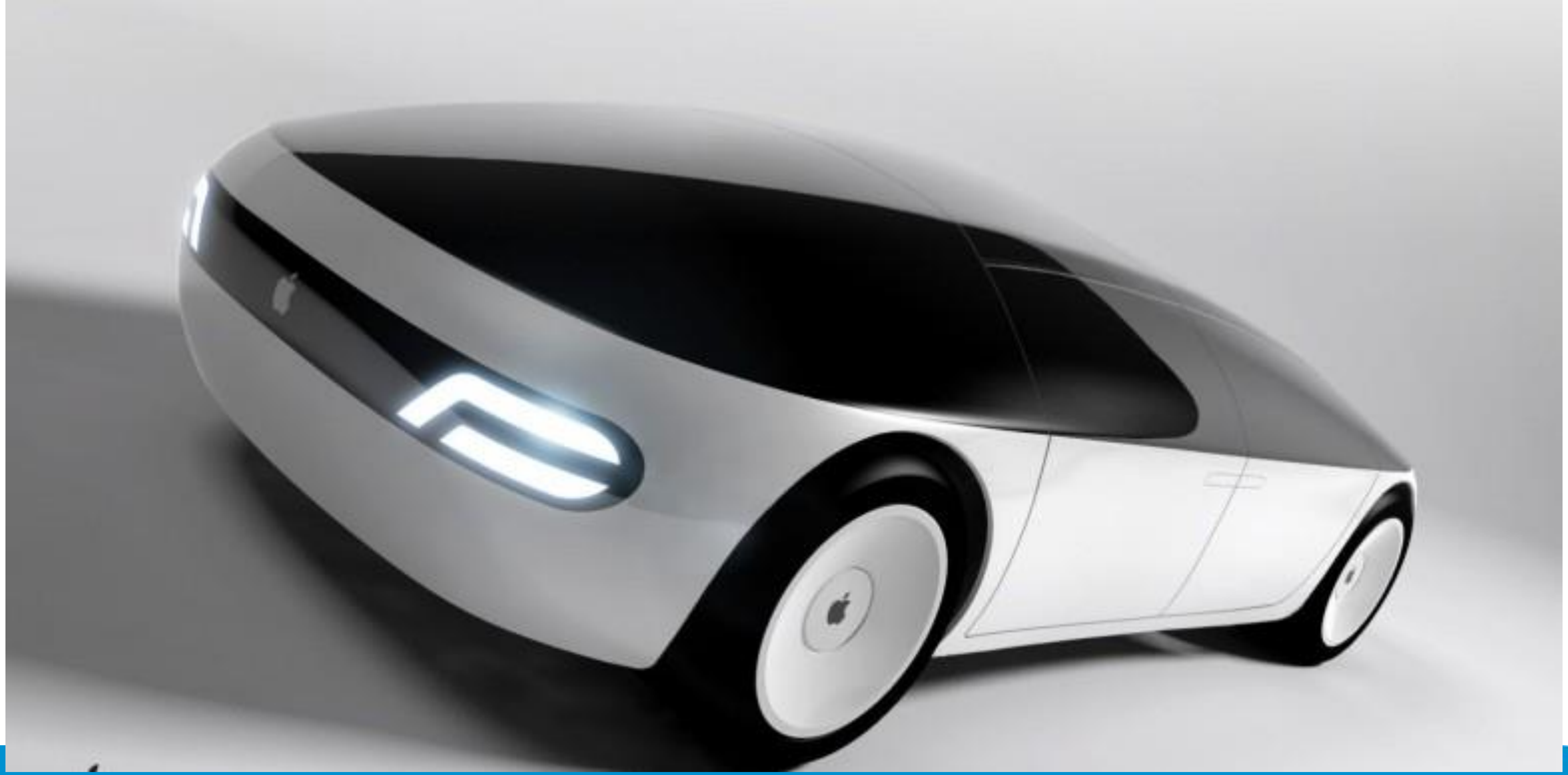
- Unlike some Silicon Valley start-ups such as **Zoox**, Aurora wants to partner with traditional carmakers (not go at it alone). Partnerships with **Hyundai** and others.
- Its vehicles have driven more than 5 million miles on public roads.

ZOOX

- **Zoox** concept car (founded by former Apple engineers)

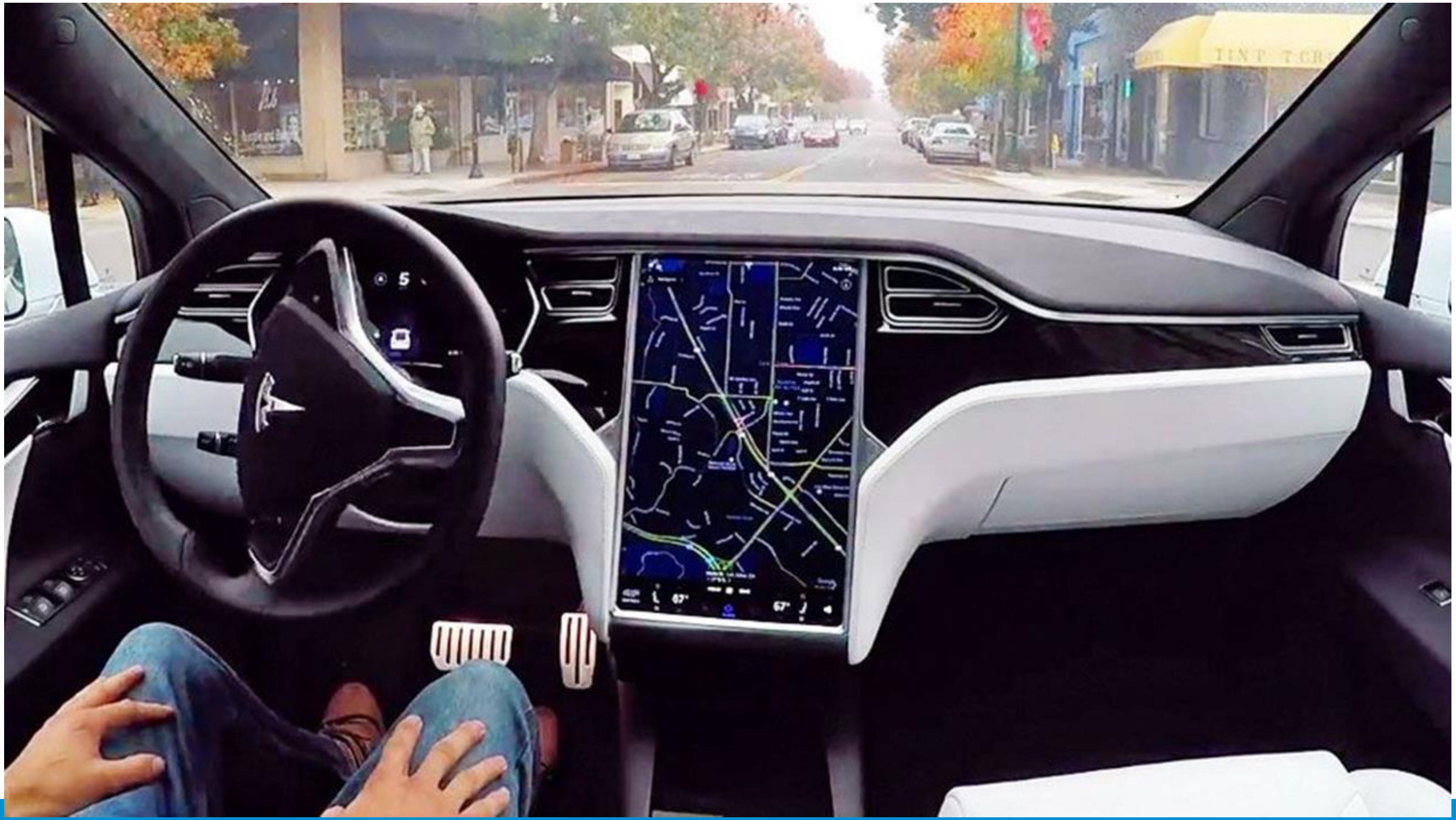
APPLE CONCEPT SELF-DRIVING CAR

- Physical car project shelved for now
- Autonomous driving system under development
- Deep integration with iOS expected
- Autonomous testing permit received from Department of Motor Vehicles (DMV)



TESLA SELF-DRIVING CAR

- All new Tesla vehicles produced, including Model 3, have the hardware needed for full self-driving capability at a safety level substantially greater than that of a human driver.



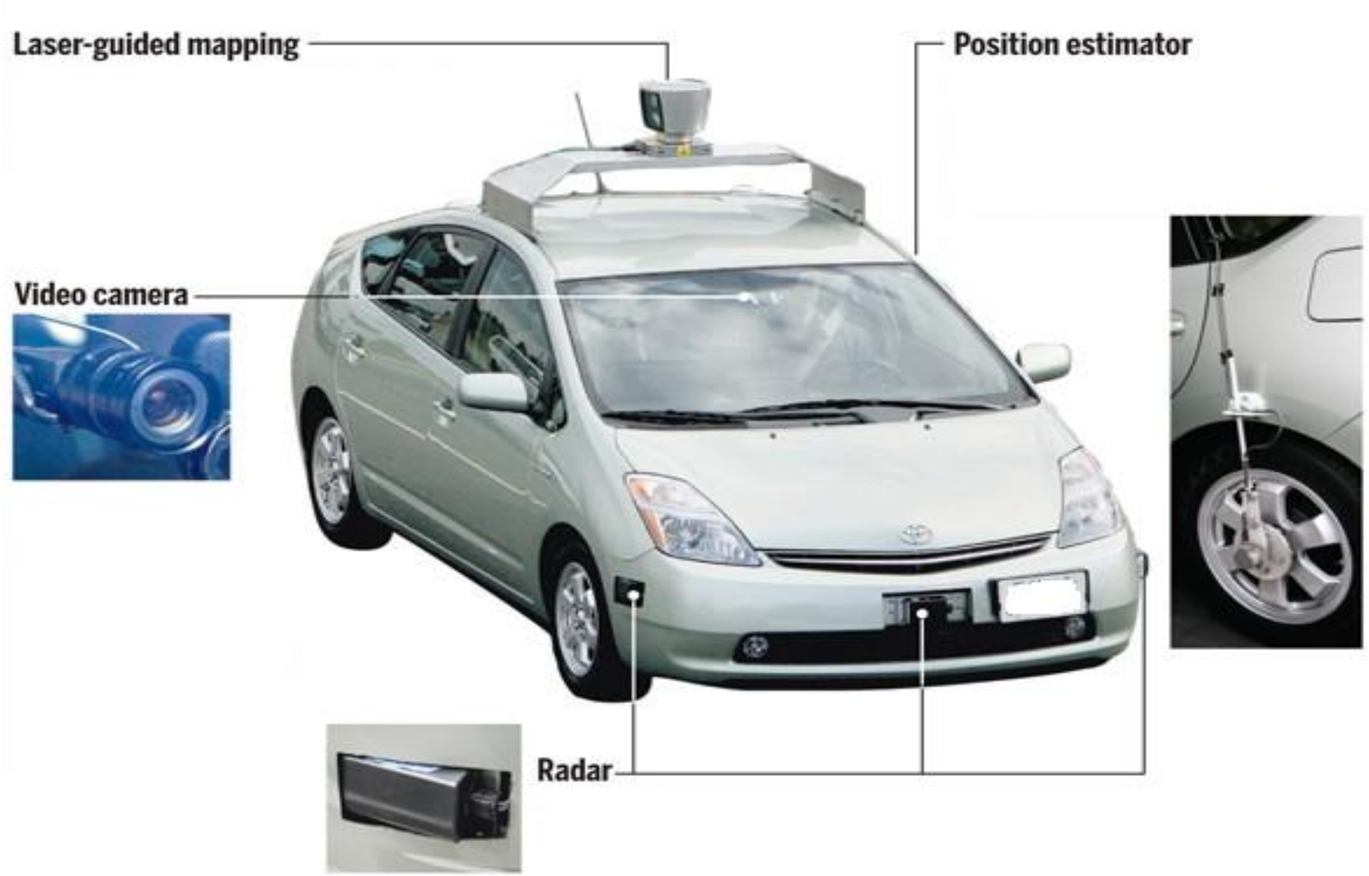
UBER SELF-DRIVING CAR

- Self-driving tests in San Francisco & Phoenix (suspended)

SELF-DRIVING CAR FATALITIES TO DATE

Date	Incident Number	Country	City	State / Province	Quantity of Fatalities	System Manufacturer	Vehicle Type	Distance Driven by System at Time of Incident	Notes	Post Accident Vehicle Photo
20 Jan 2016	1	China	Handan	Hebei	1	Tesla (Autopilot)	Tesla Model S		Driver Fatality-Truck collision	Not Available
7 May 2016	2	USA	Williston	Florida	1	Tesla (Autopilot)	Tesla Model S	130,000 miles	Driver Fatality	
18 Mar 2016	3	USA	Tempe	Arizona	1	Uber	Retrofit-Volvo		Pedestrian Fatality	
23 Mar 2018	4	USA	Mountain View	California	1	Tesla (Autopilot)	Tesla Model X		Driver Fatality	

TOYOTA PRIUS MODIFIED TO OPERATE AS A GOOGLE DRIVERLESS CAR



GOOGLE SELF-DRIVING CAR PROJECT (WAYMO)

Over 10 million miles self-driven (as of 11/15/2018)

NAVIA

World's first commercially available driverless car by France-based robotics company **Induct**.

AUTONOMOUS TRUCKS

- Fastest potential adoption (along with para-transit – small buses) and immediate economic benefit for freight companies (45% of cost of freight is labor).
- Examples of current efforts:
  - **European Truck Platooning Challenge** (2016), several participants including Daimler).
  - EU-funded **Ensemble initiative** to implement and demonstrate multi-brand truck platooning by 2021.
  - **Partially Automated Truck Platooning Demonstration** (September 2017)
    - Showcased the US Federal Highway Administration and Federal Motor Carrier Safety Administration's platooning technologies in the I–66 Corridor.
    - Heavy trucks followed each other using automated speed and spacing controls. The platooning is based on the Cooperative Adaptive Cruise Control (CACC) System.

VOLVO

Fully autonomous trucks for mining, trash collection, and other hazardous or difficult applications.

WAYMO (SUBS. OF ALPHABET)

Autonomous trucks by **Waymo** being tested on US highways

DAIMLER

Autonomous truck by Daimler testing along US highways (driver supervised) and at the CCTA's **GoMentum Station** test bed in northern California. Also testing platooning in the US and the EU.

OTTO (SUBS. OF UBER)

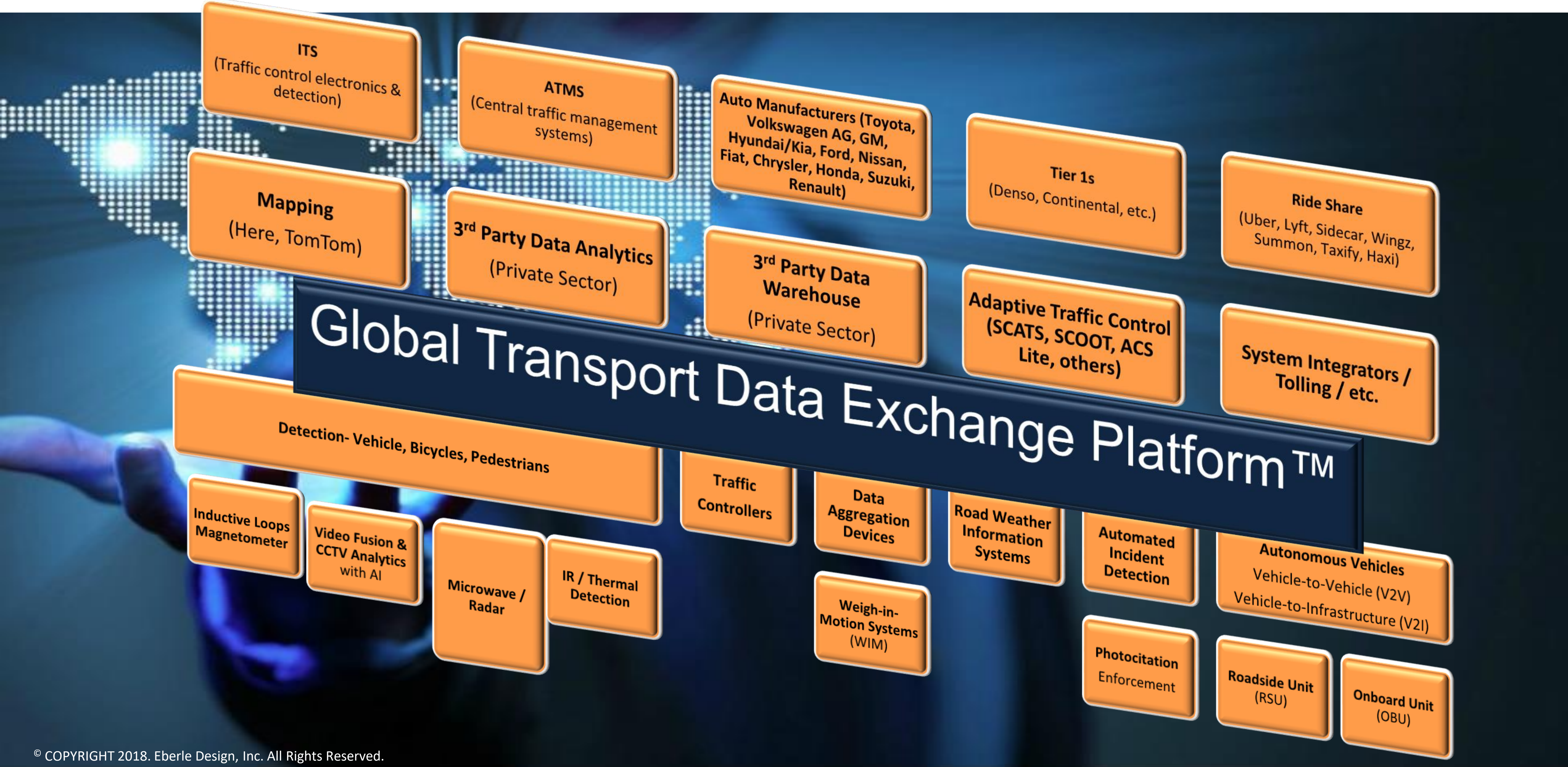
Testing in Northern California

CHALLENGES

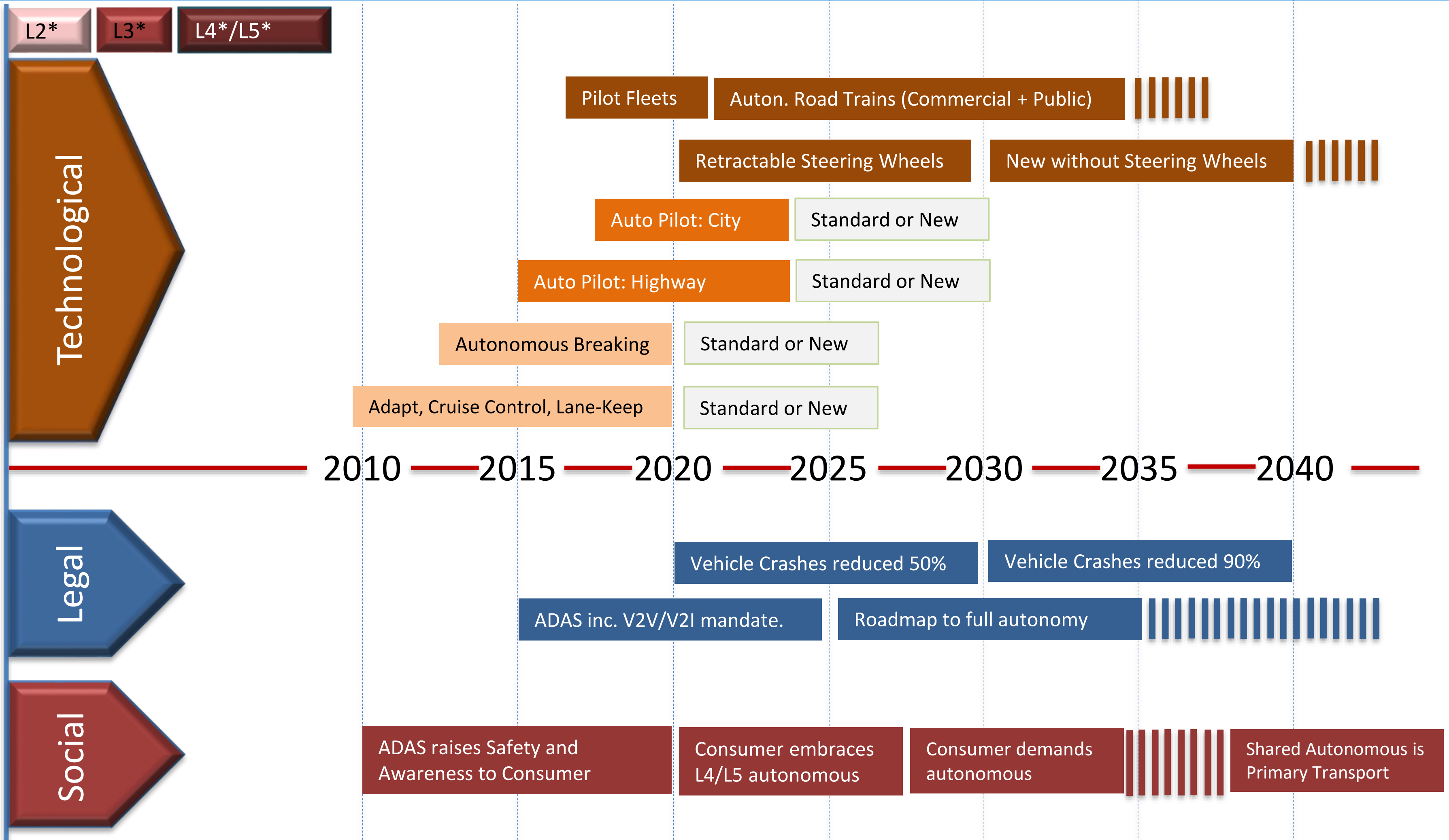
- Human drivers are still required to control the trucks, for example when truck platoons travelling on highways have to separate at junctions.
- Several other barriers remain before trucks can shed their human drivers. For starters CONNECTIVITY (as in Connected Vehicles) is essential, and across-brands and types of vehicle via a single harmonized protocol.
- Regulatory harmonization between countries (EU, NAFTA, Mercosur) is needed so that trucks can pass smoothly across borders.
- “GPS-spoofing” or hacking to redirect trucks along with their freight for theft is a threat for fleets using autonomous navigation systems
- Trailers pulled by cabs need significant changes before they can function autonomously. Trailers, which can be changed between different cabs, will have to be fitted with sensors that allow the lorry to “see” behind it and that can operate with the self-driving system of any given truck manufacturer.

THE FUTURE OF BIG TRAFFIC DATA

Traffic data collection must be hardware and detection technology agnostic.

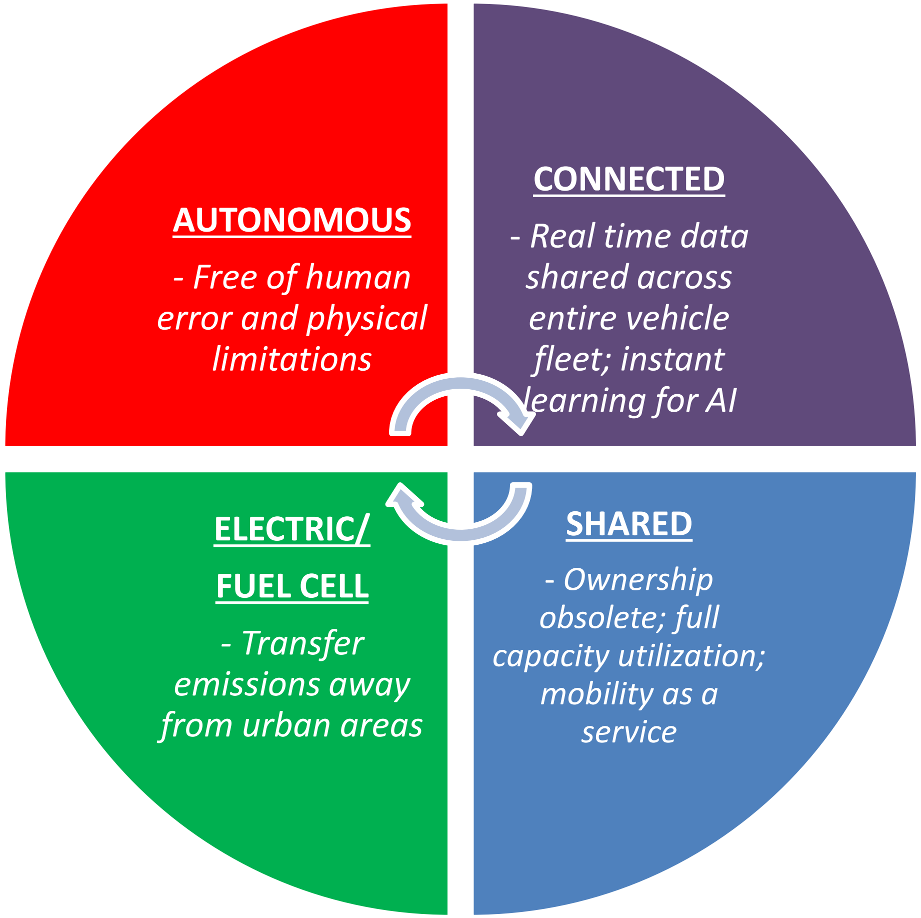


HOW MUCH LONGER?
THE ROADMAP TOWARDS FULL AUTONOMY



Source: Neckermann Strategic Advisors Assessment, June 2017

FUTURE OF URBAN MOBILITY "AUTONOMY PLUS"



PREDICTIONS AND CONCLUSIONS

OFFICIAL PREDICTIONS

By Year	Prediction
2019	MobilEye, (an Intel Company), expects to release new semi-autonomous car technology
	Audi plans to market vehicles that can autonomously steer, accelerate and brake at lower speeds, such as in traffic jams.
	Google expects to release their autonomous car technology.
	TomTom & Garmin introduce in-dash navigation equal or better than smart phone apps.
	Microsoft expects to release their autonomous car technology.
2020	Volvo envisages having cars in which passengers would be immune from injuries
	Mercedes-Benz, Audi, Nissan and BMW all expect to sell autonomous cars.
2022	Large testing of autonomous para-transit and shuttles operating at low speeds in many urban areas.
	Widespread use of autonomous (small) delivery vehicles in major urban areas.
	Successful test of fully autonomous truck-platooning
	Apple expects to release their autonomous car technology.
2035	Most vehicles will be electrically or fuel cell powered / very few internal combustion-engine powered transportation options available.
	Level 5 Fully Autonomous Vehicles can safely operate in most major cities in North America, Europe, Asia and Middle East. Most vehicles will be shared, not owned, and operated and maintained by future service companies perhaps evolved from today's automobile dealers. Cities lose revenue stream from violations.
2040	Most urban travel, in major cities, will be available by Level 5, fully autonomous vehicles

ON-GOING CHALLENGES / CONCLUSIONS

- US DOT / FHWA has failed to date to provide guidance on the deployment of a standard for wireless V2I communications (DSRC/5G/C-V2I), therefore the signalized infrastructure is not yet ready to receive the Basic Safety Message (BSM) from CAV-equipped vehicles.
- There is currently no significant funding mechanism available to upgrade the >400K US signalized intersection infrastructure to accept the vast amounts of data of CAV-equipped vehicles.
- Very few North American signalized intersections are currently able to pass the SPaT message, real-time R-Y-G timing data, and intersection MAP message back to (Level 4 and Level 5) equipped Autonomous Test Vehicles.
- The current security of C-V2I wireless messages is lacking validation and is open to interference.
- While taking human decision-making out of the mix will enhance motorist and pedestrian safety, it will add to congestion by slowing vehicular movement, and put more vehicles on the road per capita.
- With the transition from internal combustion engines to a totally electric global vehicle fleet in the future, the availability of electrical recharging stations will be a key concern.
- With the availability of Level 5 autonomous vehicles, Mobility-as-a-Service (Maas) will be the future.

Questions / Discussion

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