Where Are Self-Flying Planes and Self-Driving Cars Taking Us?

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Updated October 2023


So much
information,
so little time!

The full version of this presentation takes over two hours, so to fit the time available I'll be glossing over some of the detailed information on the slides, and I won't be covering some sections at the end such as the one on electric cars.

However, the full deck will be available for download at https://opcug.ca/presentations/2023-10-self-driving-cars.pdf

In the last few years there has been a lot of news about autonomous vehicles, especially cars and planes.

We'll find out what's happened up to now and where it's likely to go in the future.

I did the first version of this presentation in 2017, and some of the things that were supposed to have happened by ***NOW*** are ***STILL*** at least a few years away.

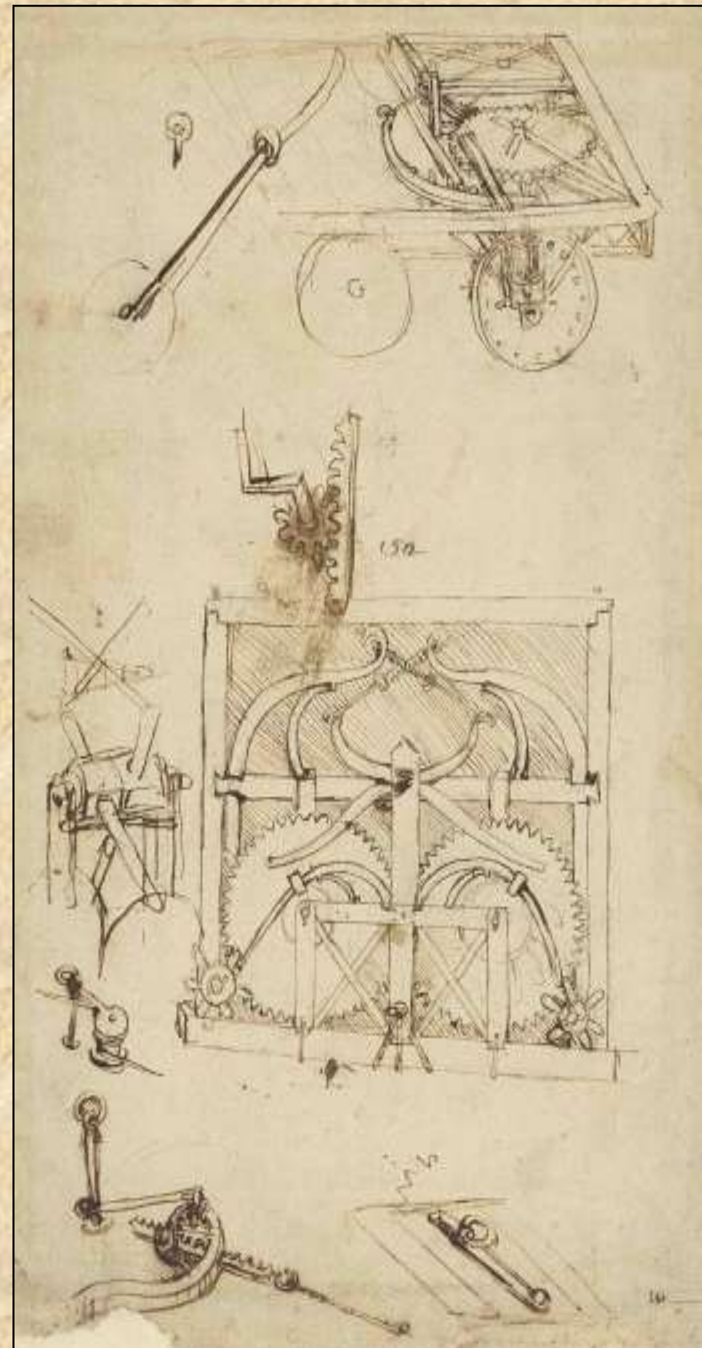
It goes back as far as **Leonardo Da Vinci**

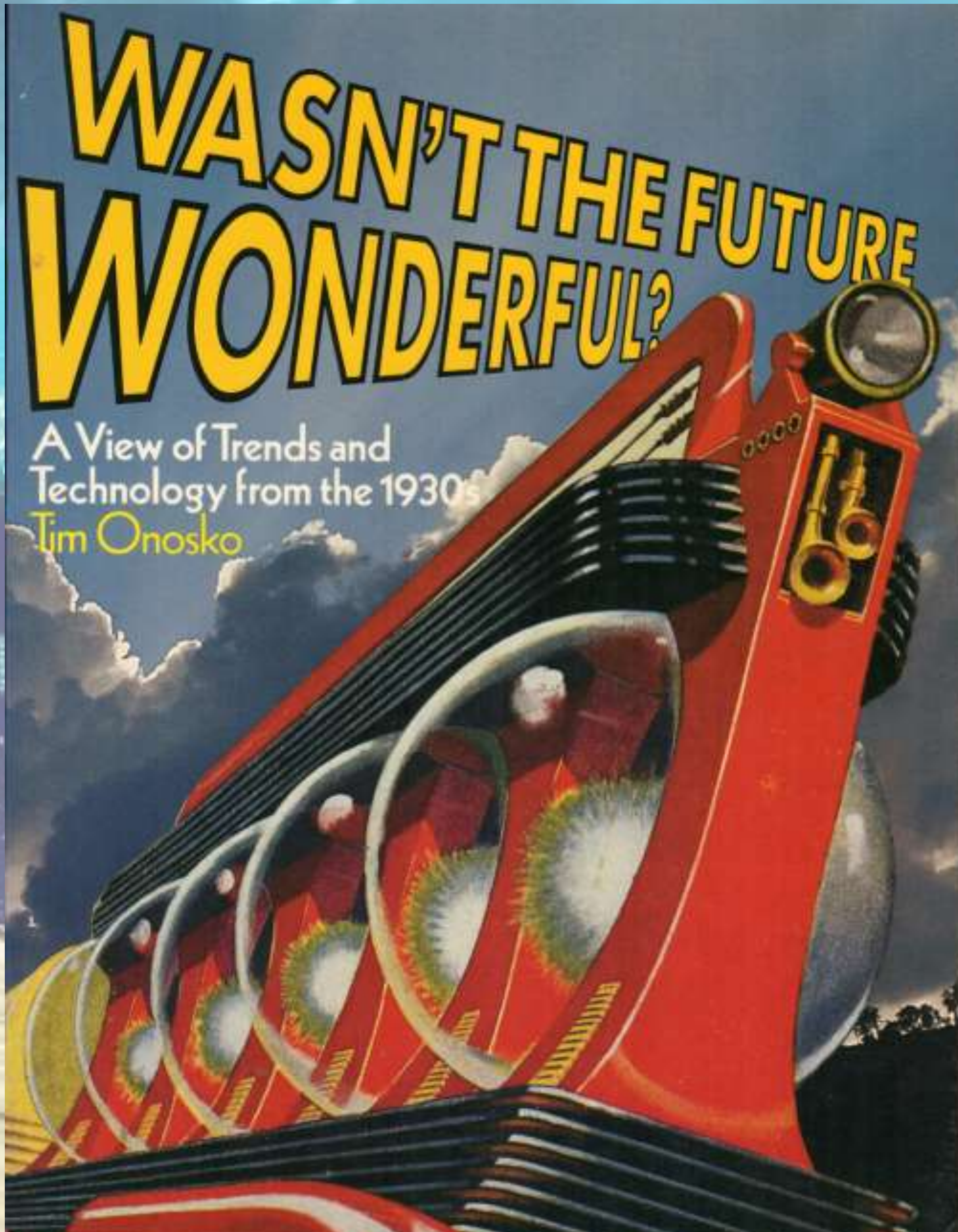
(circa 1478)

This is his sketch of a pre-programmed cart powered by large coiled springs.

The control mechanism steers the vehicle through a predetermined course.

In 2006 a working replica was made.





Back in the 1930's there were a lot of optimistic predictions on what the future was going to be like.

*“Since the 1930s self-driving cars have remained perpetually two decades away, while over the past century other autonomous and semi-autonomous vehicles have conquered the air, sea and roamed the edges of our solar system.” **

*- Computer History Museum, Mountain View, California

www.computerhistory.org

Note the special center line

This Is What They Imagined

30 Years Later This Is What They Got

Are we still 20 years away? Let’s find out!

There are three principles driving the development of autonomous vehicles

AUTONOMY

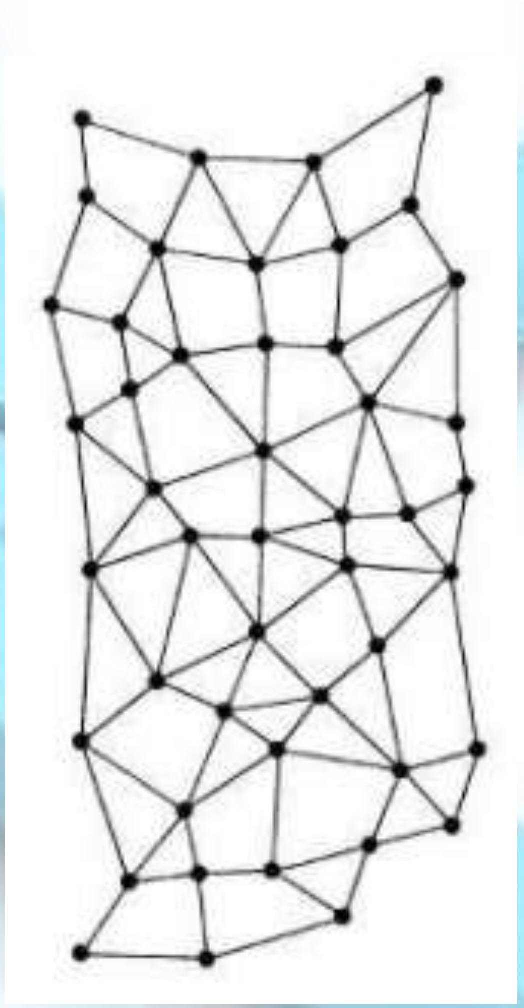
Planes and cars can use automated systems to get the vehicle from one place to the other, with the eventual goal of removing the human operators from the equation.

COOPERATION

Upcoming autonomous systems will not only have the vehicles managing themselves independently, but also *COOPERATING* with each other and with traffic control systems.

DISTRIBUTED CONTROL

Traffic control systems will feature *DISTRIBUTED* control and decision making.



Much of This Got Started With Systems for Airplanes

It Started with the Autopilot

The early autopilots permitted the aircraft to fly straight and level on a compass course without a pilot's attention.

This greatly reduced the pilot's workload!

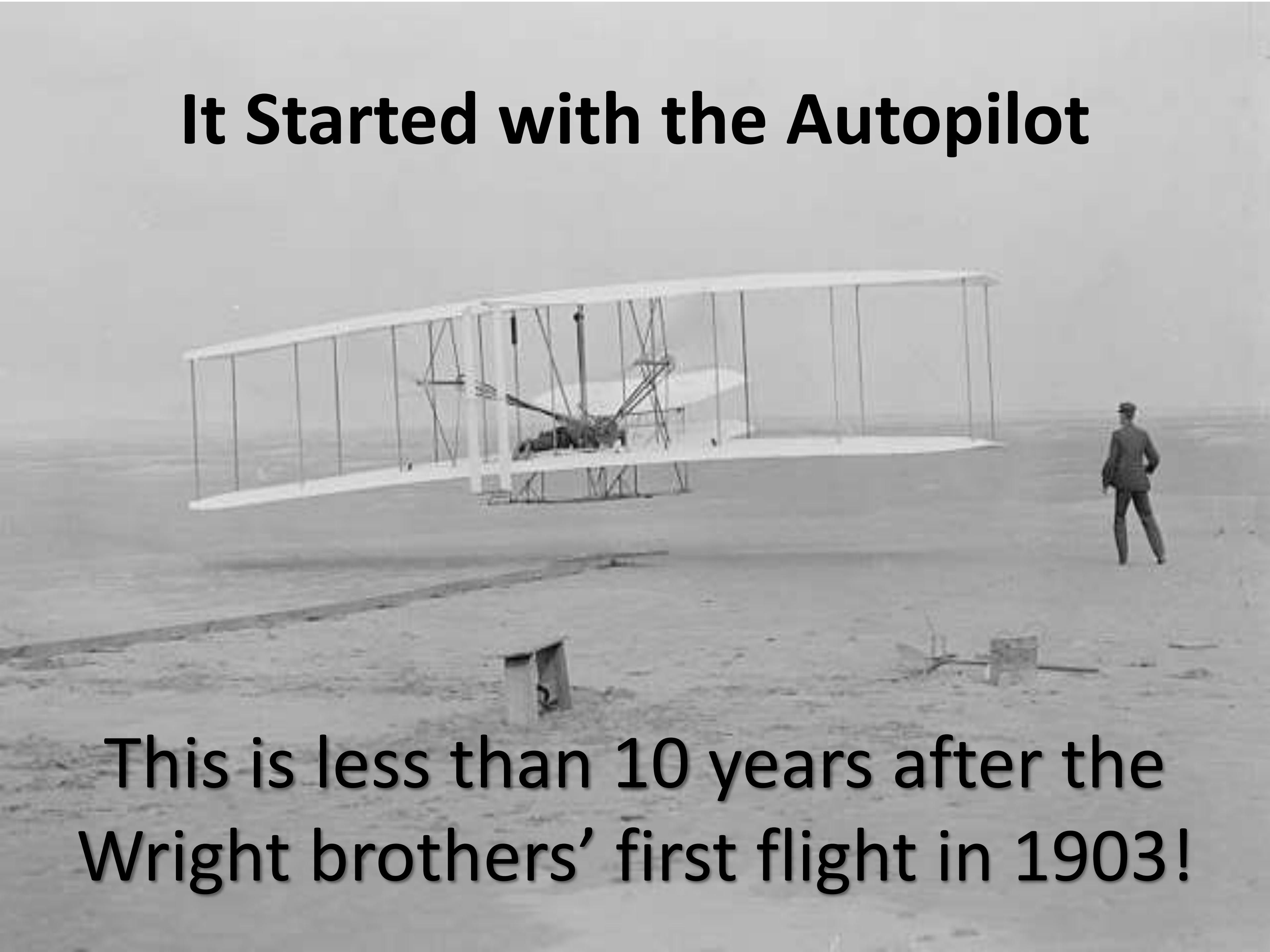
“Mechanical Mike” Autopilot, 1930s

It Started with the Autopilot

The first aircraft autopilot was developed by Sperry Corporation* in 1912.

* - Now part of Lockheed Martin

It Started with the Autopilot



This is less than 10 years after the Wright brothers' first flight in 1903!

It Started with the Autopilot

With additional instrumentation, especially radio-navigation aids on the ground, it became possible to fly and navigate at night and in bad weather.

Interconnection of the autopilot with some of this instrumentation was the start of ***Flight Management Systems***.

Radio Navigation

Radio navigation is the use of radio to determine the plane’s position using direction, distance and velocity measurements between electronic beacons on the ground and the plane.

Radio Navigation

The basic principles are measurements from/to electronic beacons, especially:

– Directions (by bearing, radio phases or interferometry)

– Distances (ranging by measurement of travel times)

– Velocity (by means of radio Doppler shift)

It Started with the Autopilot

In 1947 a US Air Force C-54 made a transatlantic flight, including takeoff and landing, completely under the control of an autopilot.

Inertial Navigation Systems (INS)

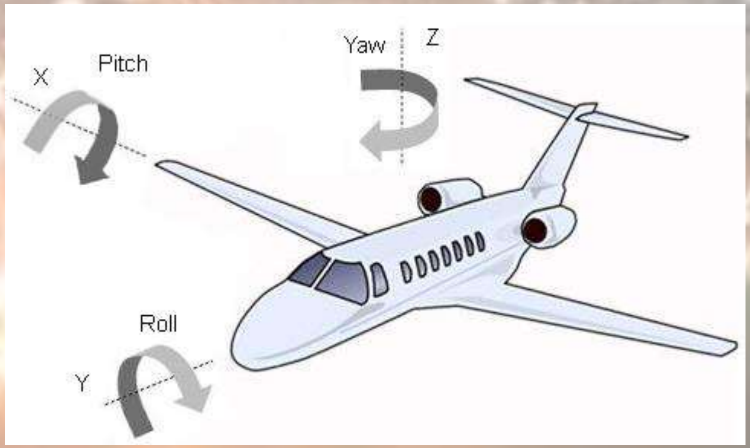
An inertial navigation system is a navigation aid that uses:

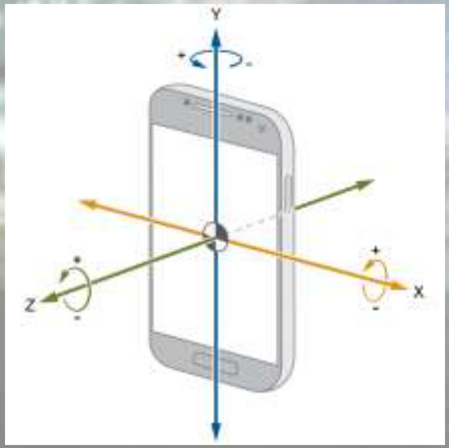
- a computer,
- motion sensors such as accelerometers, and
- rotation sensors such as gyroscopes

to continuously calculate the position, orientation, and velocity of the vessel *without the need for external references*.

Inertial Navigation Systems (INS)

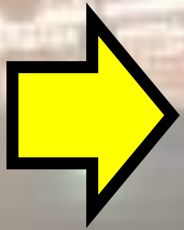
Gyroscopes sense and measure the movement around an axis

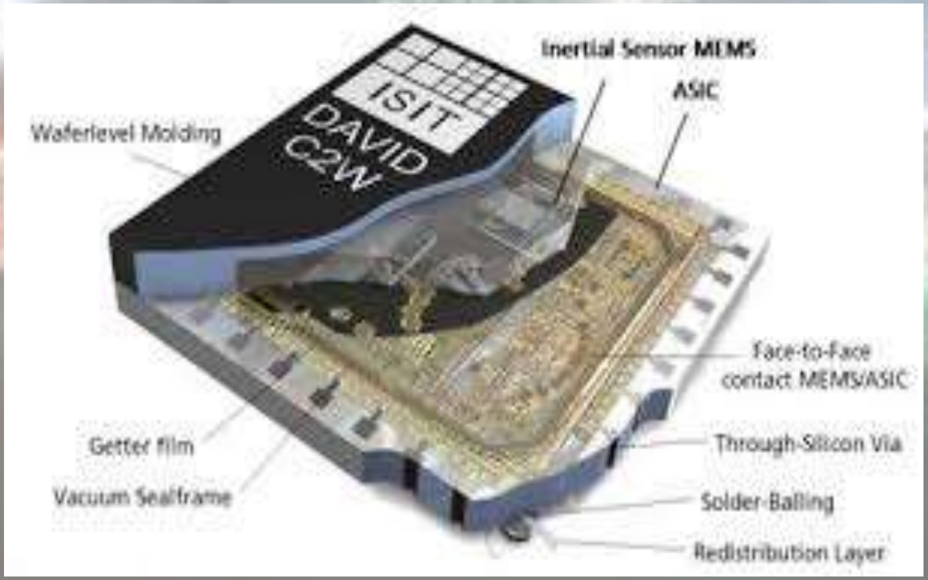




Inertial Navigation Systems (INS)

Mechanical gyroscopes have been replaced by solid state gyroscopes





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Inertial Navigation Systems (INS)

Inertial navigation is used on vessels such as:

- aircraft
- ships
- submarines
- guided missiles
- spacecraft

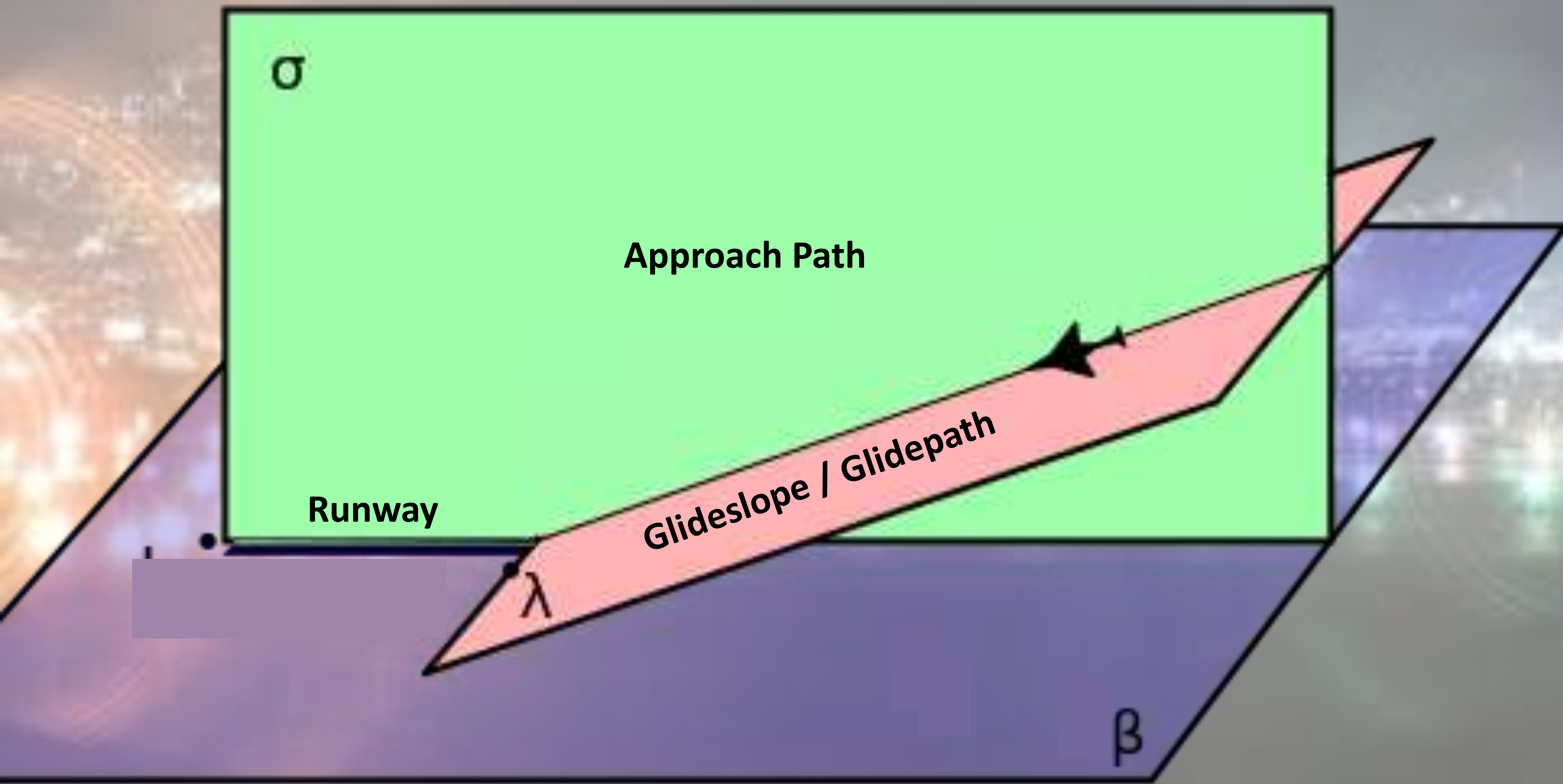
Instrument Landing Systems (ILS)

An ILS enables aircraft to land if the pilots are unable to establish visual contact with the runway.

It does this using radio signals.

ILS provides aircraft with horizontal and vertical guidance just before and during landing.

Instrument Landing Systems (ILS)



Instrument Landing Systems (ILS)

A computer interprets the radio signals and gives the pilot a display showing the course corrections required to land.

The pilot has to correct to the left and a little upwards.

Flight Management Systems (FMS)

The FMS is a specialized computer system that automates a wide variety of in-flight tasks.

It integrates the autopilot, the radio navigation systems, the ILS and other systems to do this.

Flight Management Systems (FMS)

The FMS also uses:

- A comprehensive navigation database
- The Flight Plan
- Performance information such as gross weight, fuel weight and center of gravity.

Flight Management Systems (FMS)

The Navigation Database contains all of the information required for building a flight plan, including:

- Waypoints/Intersections
- Airways
- Radio navigation aids including distance measuring equipment (DME), VHF omnidirectional range (VOR), non-directional beacons (NDB's) and instrument landing systems (ILS's).
- Airports
- Runways
- Standard Instrument Departure (SID)
- Instrument Approach Procedure (IAP)
- Standard Terminal ARrival (STAR)

Flight Plan

The Flight Plan details WHERE the plane is going, HOW it's going to get there and WHEN.

It has to be filed before taking off.

For airlines the Flight Plan is generally determined and filed by a professional dispatcher, *NOT the pilot*.

Flight Management Systems (FMS)

The Flight Plan is entered into the FMS either by:

- typing it in (prone to error so used mostly when diverting to alternate destinations)
- selecting it from a saved library of common routes
- via an ACARS datalink with the airline dispatch center.

Flight Management Systems (FMS)

The main task of the FMS is to determine the aircraft's position and use that position information to keep the aircraft on the course determined by the flight plan.

Aircraft Communications Addressing and Reporting System (ACARS)

ACARS is a digital datalink between aircraft and ground stations which allows ground personnel to monitor aircraft performance and allows them to control some aspects of that performance directly *without the pilot's involvement*.

Aircraft Communications Addressing and Reporting System (ACARS)

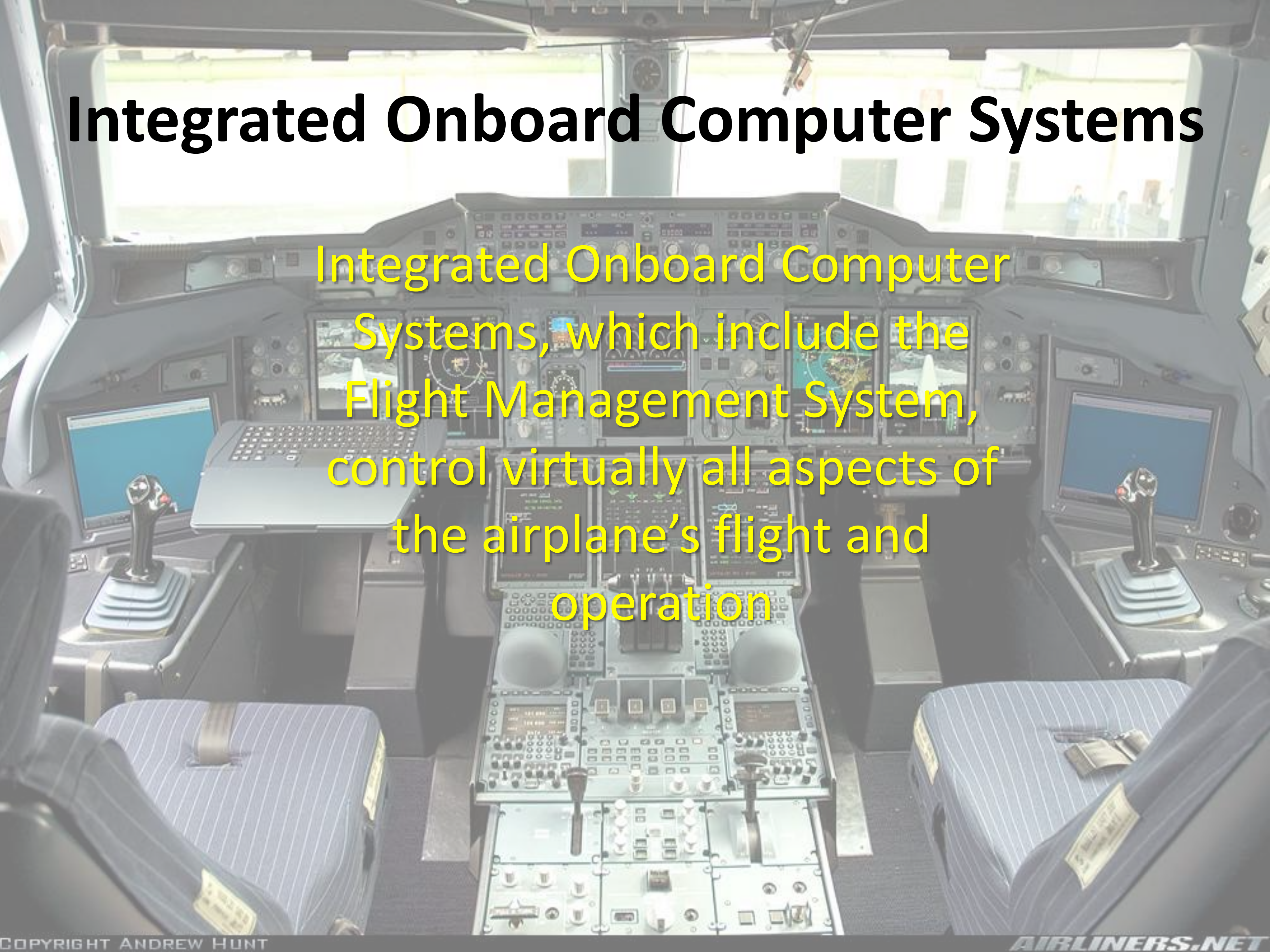
Prior to ACARS all communication between the aircraft and ground personnel was performed by the flight crew using voice communication.

ACARS has range limitations similar to the aircraft radios.

With Flight Management Systems and ACARS, the pilot is becoming less and less essential to the <u>NORMAL</u> operation of the airplane!!!

Integrated Onboard Computer Systems

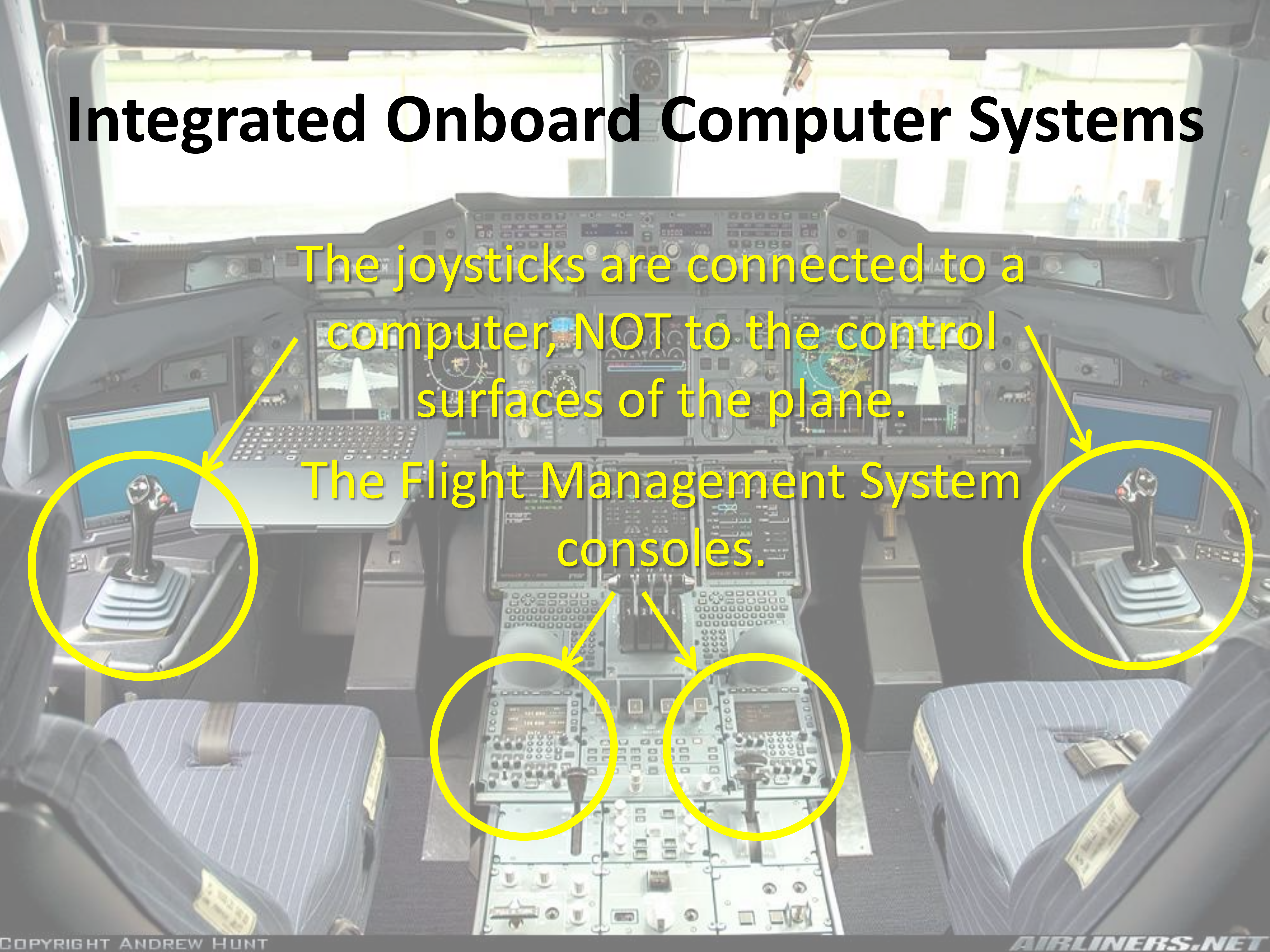
Integrated Onboard Computer Systems, which include the Flight Management System, control virtually all aspects of the airplane's flight and operation



Integrated Onboard Computer Systems

The joysticks are connected to a computer, NOT to the control surfaces of the plane.

The Flight Management System consoles.



Integrated Onboard Computer Systems

Boeing's theory of operation is that all of the automated systems are there to assist the pilots, but in the end the pilot is in control.

Boeing retains the conventional control yoke in most of its aircraft.

Integrated Onboard Computer Systems

Boeing's theory of operation can be problematic when the pilots don't understand the complex systems and thus can't take control away when they malfunction (e.g., 737 MAX accidents)

Integrated Onboard Computer Systems

Airbus' theory of operation is that all of the automated systems are there to prevent the pilots from making mistakes, and will override the pilots to do that.

Airbus has replaced the conventional control yoke with a joystick.

Integrated Onboard Computer Systems

Airbus’ theory of operation has caused some accidents because when the automated systems malfunctioned the pilots weren’t able to take over control.

Integrated Onboard Computer Systems

PROBLEM 1: Pilots have become so dependent on complex onboard systems that they have forgotten how to fly the plane!!!

Integrated Onboard Computer Systems

PROBLEM 2: Pilots don't understand many critical aspects of how the automated systems work!!!

Integrated Onboard Computer Systems

- Air France Flight 296 (Airbus A320-111) - The plane was performing a flypast at low height and speed over the runway for an airshow with the gear down. The automated system thought the plane was landing and throttled back the engines. By the time the pilot realized what was happening it was too late to throttle back up and the plane crashed into a forest at the end of the runway. Three passengers died and about 50 were injured. The pilot was thrown under the Airbus.
- Eastern Air Lines Flight 401 (Lockheed L-1011-1 Tristar) crashed into the Florida Everglades while the entire flight crew was preoccupied with a burnt-out landing gear indicator light. They failed to notice that the autopilot had inadvertently been disconnected and, as a result, the aircraft gradually lost altitude and crashed. 163 passengers died, 75 passengers and crew survived.
- XL Airways Germany Flight 888T (Airbus A320-200) – Two of the three angle of attack sensors froze and the plane stalled. The pilots did everything properly to recover from the stall but the computer overrode them and the plane crashed. All 7 on board were killed.
- China Airlines Flight 006 (Boeing 747SP) - Autopilot couldn't correct for the failure of the No. 4 engine. The plane rolled over and plunged 30,000 ft (9,100 m), experiencing high speeds and g-forces (approaching 5g) before the captain was able to recover from the dive. Boeing claims the pilot needed to be able to overstress the plane to recover it, which an Airbus wouldn't let the pilot do. Airbus says their plane wouldn't have got into trouble in the first place.
- Aeroflot Flight 593 (Airbus A310-300) Pilot allowed his kids on the flight deck and his son sat in the pilot's seat. The son had unknowingly disengaged the autopilot's control over the aircraft's ailerons while seated at the controls. The aircraft rolled into a steep bank and near-vertical dive. 75 people were killed.
- Air France Flight 447 (Airbus A330-203) - The aircraft's pitot tubes (used to measure airspeed) iced over leading the autopilot to disconnect and handing full control of the aircraft to the pilots. The pilots were confused by various warnings and messages from the aircraft's on board systems and pulled the nose of the plane up to the point where the aircraft stalled. The pilots failed to recognize that the aircraft had stalled until it was too late to prevent an uncontrolled and rapid descent into the Atlantic Ocean. All 228 people on board were killed.
- US Airways Flight 1549 (Airbus A320-214) - "Miracle on the Hudson". The plane lost both engines because of a bird strike. During the successful ditching in the Hudson River in New York, the Airbus onboard computer systems kept the plane from stalling and kept the wings level. All 155 people on board survived with only 1 significant injury.

Paris crash video

www.youtube.com/watch?v=-kHa3WNerjU

More info at

en.wikipedia.org/wiki/Air_France_Flight_296

Air Traffic Control (ATC) Systems

The primary purpose of ATC worldwide is to:

- Prevent collisions
- Organize and expedite the flow of air traffic
- Provide information and other support for pilots

ATC Radar

ATC primarily uses radar to keep track of the planes and voice radio to communicate with the plane.

Transponders

- A transponder is an electronic device that produces a response when it receives a radio or radar signal.
- Aircraft have transponders to assist in identifying them on radar

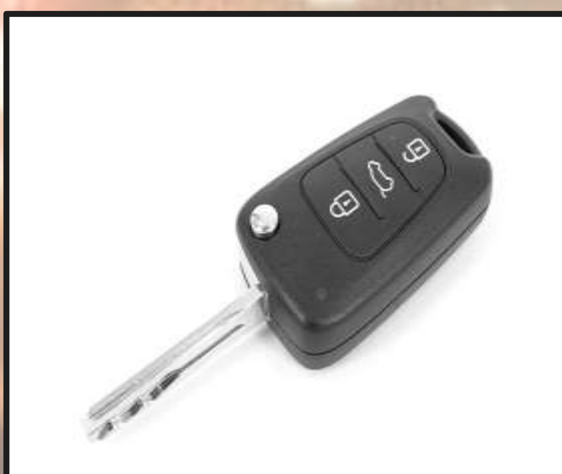
Radar Screen Showing Transponder Information

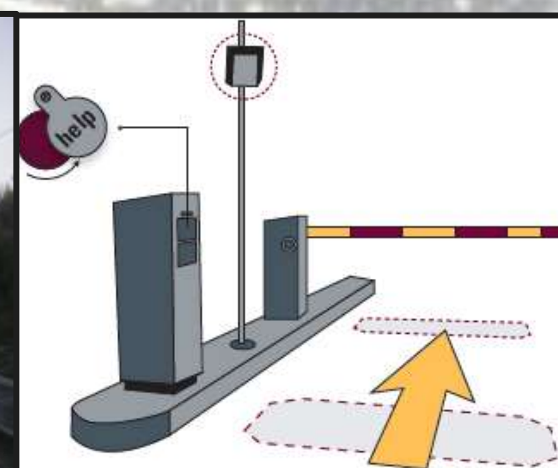
E.g. British Airways Flight 295 at 34,000' altitude

This type of radar is becoming obsolete

Transponders

Transponders are also used in cars for things like remote car keys, toll collection on toll roads, paying parking fees, etc.





Traffic Collision Avoidance System (TCAS)

TCAS monitors the airspace around an aircraft for other aircraft equipped with a corresponding active transponder and warns the pilots of the threat of a mid-air collision.

TCAS only works between two planes equipped with TCAS enabled active transponders

Traffic Collision Avoidance System (TCAS)

The aircraft ‘talk’ to each other and ***cooperatively*** deal with the situation ***without*** Air Traffic Control

Traffic Collision Avoidance System (TCAS)

TCAS Verbal Warnings

Warning	Meaning	Required action
Traffic; traffic.	Intruder near both horizontally and vertically.	Attempt visual contact, and be prepared to manoeuvre if an RA occurs.
Climb; climb.	Intruder will pass below	Begin climbing at 1500–2000 ft/min
Descend. Descend.	Intruder will pass above.	Begin descending at 1500–2000 ft/min

Traffic Collision Avoidance System (TCAS)

TCAS Video

www.youtube.com/watch?v=OrYqIU0NxHQ

Traffic Collision Avoidance System (TCAS)

When TCAS instructions conflict with Air Traffic Control instructions, ***TCAS is to take precedence***

Überlingen collision: Bashkirian Airlines Flight 2937 (Tupolev Tu-154 passenger jet) and DHL Flight 611 (Boeing 757 cargo jet), collided in mid-air over Überlingen, Germany. All 69 passengers and crew aboard the Tupolev and the two crew members of the Boeing were killed.

The only air traffic controller handling the airspace was working two workstations at the same time. He failed to keep the aircraft at a safe distance from each other. When he finally realized the danger he instructed the pilot of Flight 2937 to descend. Seconds later TCAS) instructed them to climb, while at about the same time the TCAS on Flight 611 instructed the pilots of that aircraft to descend. Had both aircraft followed those automated instructions, the collision would not have occurred.

A year and a half after the crash, Peter Nielsen, the air traffic controller on duty at the time of the collision, was murdered in an apparent act of revenge by Vitaly Kaloyev, a Russian citizen who had lost his wife and two children in the accident.

Traffic Collision Avoidance System (TCAS)

TCAS commands are ***still*** by voice and ***still*** require the pilots to carry them out.

BUT NOT FOR LONG!

NextGen Air Transportation System

The Next Generation Air Transportation System (NextGen) will transform America's air traffic control system -

From: a radar-based system with voice communication via radio.

To: a GPS based system with digital communication via satellite.

NextGen Air Transportation System

NextGen technology will be used to:

- shorten routes
- save time and fuel
- reduce traffic delays
- increase airway capacity
- permit controllers to monitor and manage aircraft with greater safety margins

NextGen Air Transportation System

Radio communications will be increasingly replaced by data exchange

Increased automation will reduce the amount of information the air crew must process at one time

NextGen Air Transportation System

NextGen will automate much more of the air traffic control system and will have airplanes ***cooperatively*** managing separation and other flight aspects between themselves ***without*** involving the larger system.

NextGen Air Transportation System

TCAS will be unnecessary as the airplanes 'talk' to each other and make minor course corrections long before it becomes a problem.

The pilots will ***NOT*** be significantly involved.

SESAR – Europe's NextGen and More

Single **E**uropean **S**ky **A**TM **R**esearch (SESAR) is Europe's version of NextGen.

SESAR and NextGen technologies will be compatible with each other.

SESAR – Europe's NextGen and More

SESAR also unifies all European airspace into a single air traffic control zone

It Started with the Autopilot

Over time this has led to the development of :

- Flight Management Systems (FMS)
- Aircraft Communications Addressing and Reporting System (ACARS)
- Integrated Onboard Computer Systems

} **Control of the Aircraft**

- Radio Navigation
- Inertial Navigation Systems (INS)
- Global Positioning Systems (GPS)

} **Navigation**

- Air Traffic Control (ATC) Systems
- Traffic Collision Avoidance System (TCAS)
- **NextGen** Air Transportation System
- Single European Sky ATM Research (SESAR)

} **Cooperation**

Do We Still Need Pilots?

It’s not clear when the pilot on board will become unnecessary, but as automated systems take a bigger and bigger role, the role of the pilot becomes smaller and smaller.

But Planes Have It Easy

- Planes operate in a much more controlled environment (no kids or deer running across the sky).
- There are thousands of possible destinations instead of tens of millions, and hundreds of thousands of route combinations instead of hundreds of millions.
- It’s OK if the control system on the plane costs a few million $$$$$, where for cars it has to be a few thousand $$$$$.
- The support infrastructure for planes is worth many many billions of $$$$$, for an autonomous car it’s a ‘nice to have’ but the car has to be able to self-drive all on its own.
- A plane has skilled, qualified pilots able to take control if something goes wrong, whereas some future self-driving cars may not even have a steering wheel.


Now we’ll see how
some of what we’ve
covered so far applies
to autonomous cars

Autonomous Cars

An autonomous car

(also known as a driverless car, self-driving car, robotic car)

is a vehicle that is capable of sensing its environment and navigating without human input.

Autonomous Cars

Autonomous vehicles sense their surroundings with such techniques as

- radar
- lidar
- ultrasound
- GPS
- computer vision

in order to drive themselves, at least to a certain degree.

Semi-Autonomous Cars

Many semi-autonomous features are already available in production cars.

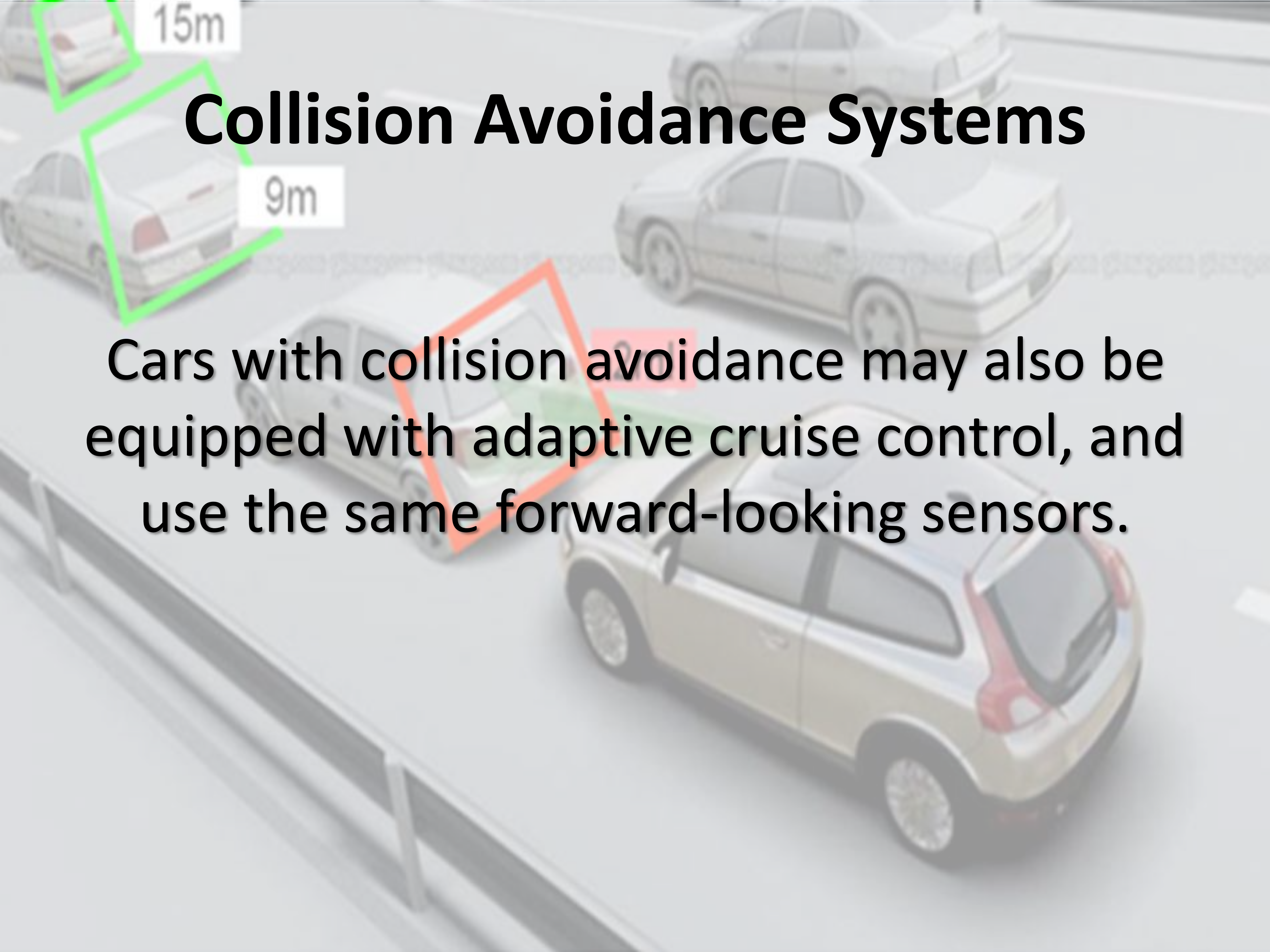
- Collision avoidance
- Adaptive cruise control
- Lane keeping
- Blind spot monitoring
- Cross traffic alert
- Self-parking

Collision Avoidance Systems

A collision avoidance system uses radar, lidar, ultrasound and/or image recognition to detect an imminent danger (e.g. another car, pedestrians, deer) and take action autonomously by braking without any driver input.

Collision Avoidance Systems

Cars with collision avoidance may also be equipped with adaptive cruise control, and use the same forward-looking sensors.



Collision Avoidance Systems

Many systems in current use have a relatively short range, especially with ‘smaller’ objects like children and animals, and if the vehicle is traveling at highway speeds the range may be insufficient to allow the vehicle to stop in time.

Collision Avoidance Systems (Automatic Emergency Braking)

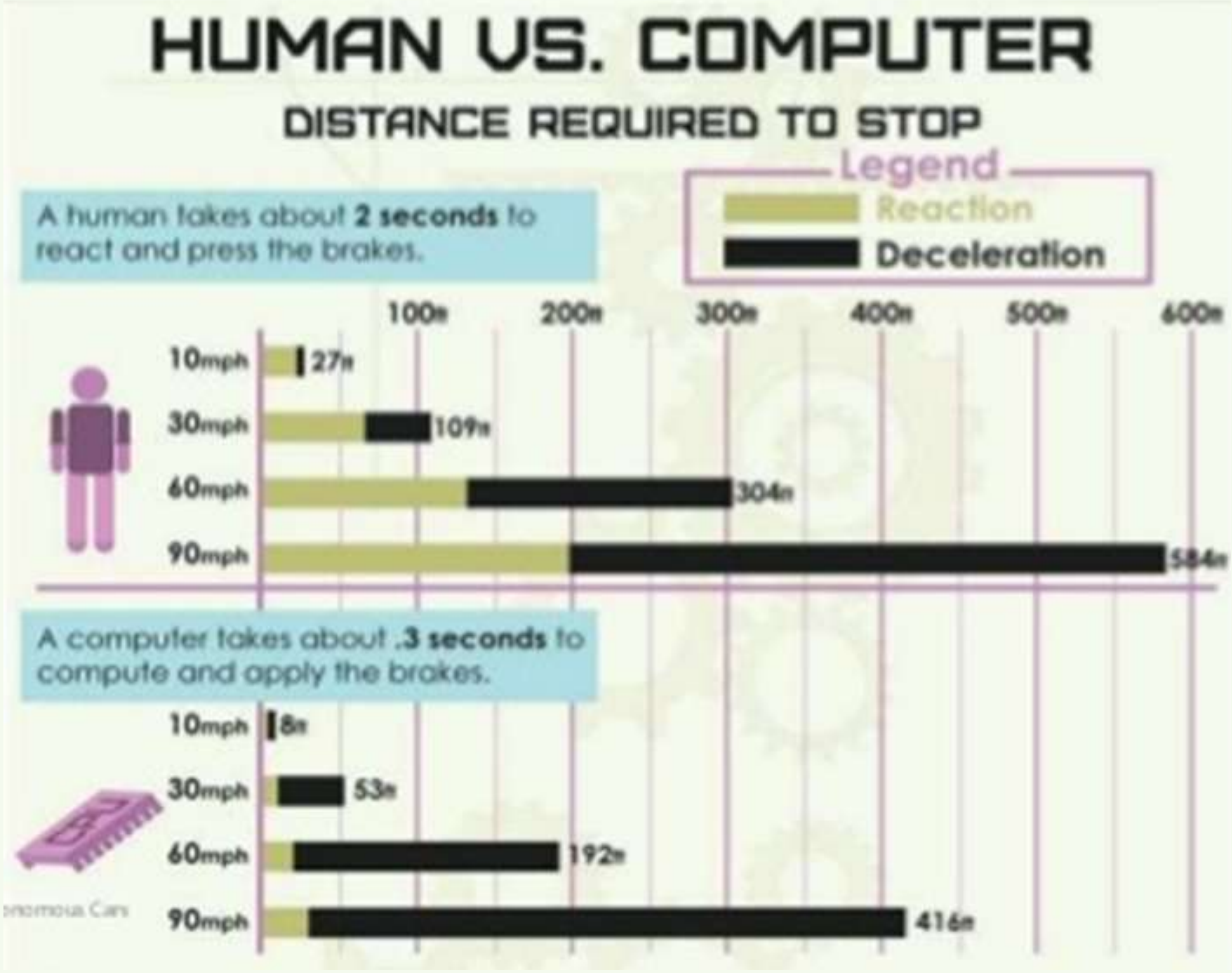
In tests by the IIHS* in 2018, the only current model car (a Tesla Model 3) that reliably stopped for fixed objects (e.g., walls, stopped cars) also stopped for tree shadows on the road.

Many systems are much more reliable when the Adaptive Cruise Control was turned on.

In the tests, some cars braked earlier and smoother, whereas some slammed on the brakes at the last second.

*** - IIHS - Insurance Institute for Highway Safety**

Reaction Time



Collision Avoidance Systems

The actual distance to stop <u>*once the brakes have been applied*</u> is identical between humans and computers.

The difference is that computers react within a few thousands of a second, whereas it takes a human up to two or more seconds to react and apply the brakes.

Since 2015, the U.S. National Highway Traffic Safety Administration (NHTSA) has recommended Automatic Emergency Braking (AEB) for vehicles. As of 2021, it is still not mandatory in the US vehicles. However, in 2016, the NHTSA convinced automobile manufacturers to include AEB in 99% of new cars car sold in the US by 1 September 2022.

In the European Union, advanced emergency-braking system is required by law on new vehicle models from May 2022, and all new vehicles sold by May 2024.

Adaptive Cruise Control (ACC)

- **Adaptive cruise control (ACC)** automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead, then accelerate up to the set speed when traffic allows.
- **ACC with Stop & Go**, combined with a **Collision Avoidance System**, allows the vehicle to autonomously come to a complete stop and then get going again (without driver intervention) in stop and go traffic.

Lane Departure Warning Systems

There are three main types of systems:

1. Lane Departure Warning (LDW) warns the driver if the vehicle is leaving its lane by visual, audible, and/or vibration warnings
2. Lane Keeping System (LKS) warns the driver and, if no action is taken, automatically takes steps to ensure the vehicle stays in its lane. Left to its own devices it may wander between the left and right lane limits.
3. Lane Centering Assist (LCA) proactively keeps the vehicle in the center of the lane

Types 2 and 3 differ mainly in software, not hardware

Lane Departure Warning Systems

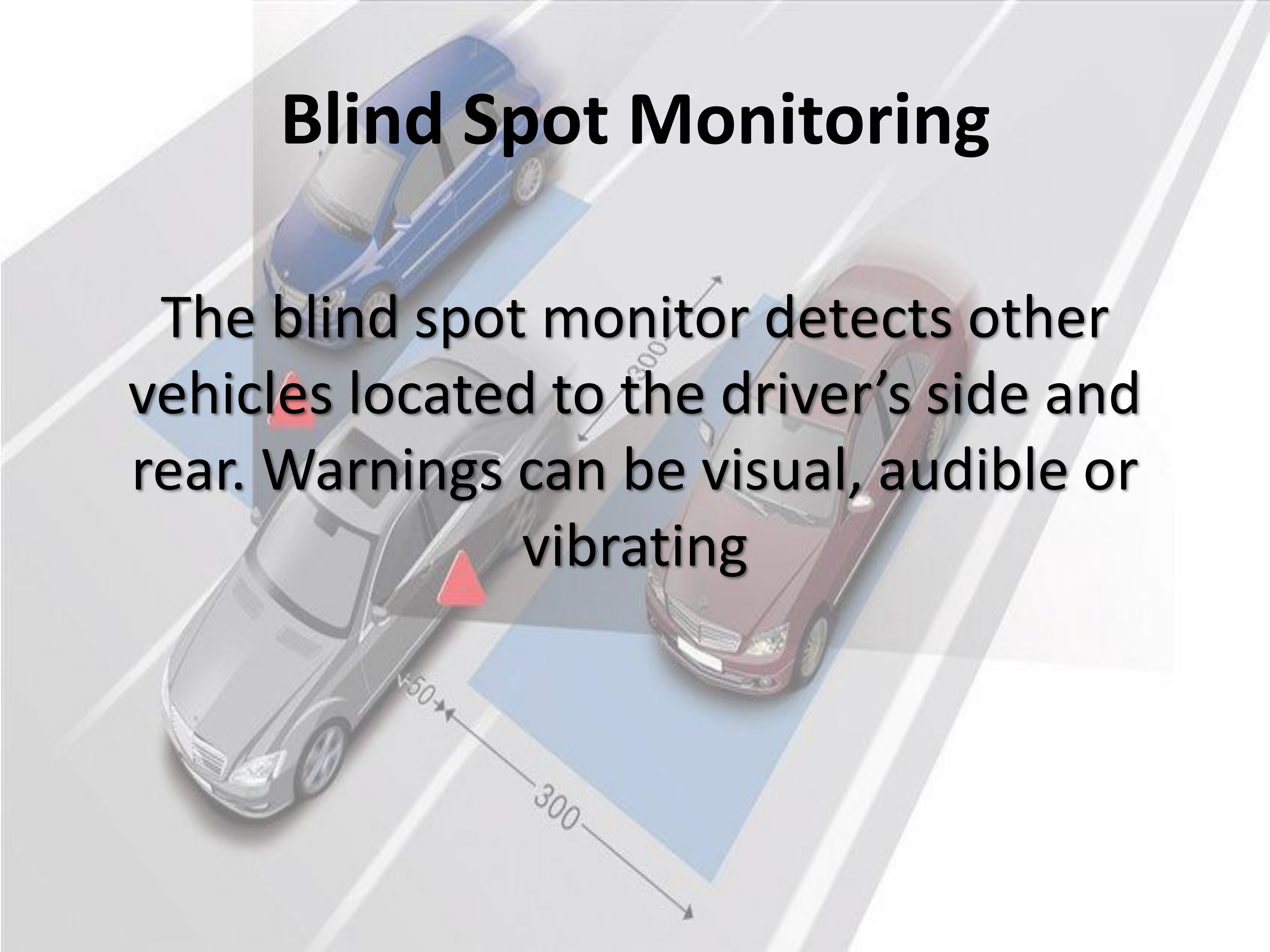
All three types of systems rely primarily on visible lane markings. They sometimes have difficulty distinguishing between the pavement and the curb or the shoulder.

They typically cannot decipher faded, missing, or incorrect lane markings.

Markings covered in snow, or old lane markings that are still visible, can hinder the ability of the system.

Blind Spot Monitoring

The blind spot monitor detects other vehicles located to the driver's side and rear. Warnings can be visual, audible or vibrating



Blind Spot Monitoring

Some cars (e.g. Tesla) integrate the blind spot monitor with their “Autopilot” system for automatic lane changes.

When the turn signal is activated the car checks to the side and back, and if it is clear will make the lane change ***without the driver even having to touch the steering wheel***.

Blind Spot Monitoring

Some cars with blind spot monitoring do a poor job detecting cars coming up quickly in another lane on the freeway.

In some cars like Honda, the screen in the dashboard shows the view from a camera built into the appropriate side-view mirror when you activate the turn signal to change lanes.

Cross-Traffic Alert

Warns you if you're about to back out of your parking spot into traffic or a pedestrian.

Some systems apply the brakes if you don’t.

The systems have range limitations and some systems don’t detect fast moving vehicles in time.

Self-Parking

Automatic parking (self-parking) moves a vehicle from a traffic lane into a parking spot to perform parallel, perpendicular or angle parking.

In some systems the driver doesn't even have to be in the car. You activate the self-parking from your key fob or an app on your smart phone.

Semi-Autonomous Cars

Some manufactures including Tesla, Mercedes, Audi, Volvo, Infiniti and Cadillac combine ***Adaptive Cruise Control*** with ***Lane Centering Assist*** and ***Collision Avoidance***, sometimes in combination with other systems, to make the vehicle semi-autonomous.

Semi-Autonomous Cars

The list of semi-autonomous capable vehicles is constantly growing, although most of them require you to keep your hands on the steering wheel.

ALL of these vehicles still require the driver to maintain control and responsibility for the vehicle while using these systems.


Semi-Autonomous Cars
Many drivers of current semi-autonomous cars tend to WILDLY over-estimate the real world capabilities of their cars!!!
Thatcham Research
https://www.wired.com/story/semi-autonomous-systems-safety-research-euro-ncap-thatcham/

Semi-Autonomous Cars

Humans are the weakest link in semi-autonomous vehicles such as Tesla's Autopilot system.

> ***"Maybe these intermediate levels [of automation] are not a viable consumer product. They go a little too far in encouraging drivers to check out and yet <u>they [the drivers] aren't ready to take control</u>."* ***

*** - Richard Wallace, the director of the Transportation Systems Analysis group within the Center for Automotive Research**

Hyundai - The Empty Car Convoy Video

www.youtube.com/watch?v=mjhXE7DmnUs

Making the Empty Car Convoy Video

www.youtube.com/watch?v=bQYXrRSMsA4

General Motors Super Cruise Hands-Free Driving Assist

- **GM spent several years LiDar mapping over 400,000 kilometers of roadways in the U.S. and Canada*.**
- **These LiDar scans provide inch-perfect views of the roads that the car's computer processes and uses in conjunction with the real-time sensors to read the road and pilot the car.**
- **They're constantly re-driving and updating the scans to account for construction work, and road re-routing.**

*** - In Canada 80,000 kilometers have been mapped**

General Motors Super Cruise Hands-Free Driving Assist

While semi-autonomous systems are reactive, GM's system is more predictive.

Like other systems, it uses several sensors to view the world around it, but it knows when construction zones or tight turns are coming up and will slow you down if necessary and will resume full speed afterwards.

General Motors Super Cruise Hands-Free Driving Assist

The Super Cruise function could only be used originally on limited access highways (i.e. no traffic lights, no pedestrians, fewer complex situations), and requires the driver to take over in construction zones or other unusual situations.

GM is expanding the Supercruise network to include some regular highways such as the TransCanada, Route 66 and the Pacific Coast Highway.

General Motors Super Cruise Hands-Free Driving Assist

The car uses a small camera mounted on the steering column to track when your eyes are on the road and when they're wandering.

General Motors Super Cruise
Hands-Free Driving Assist

Depending on the speed you're travelling, you're ‘allowed’ to look away for between 4 and 11 seconds.

The faster you go, the shorter the time you can look away from the road.

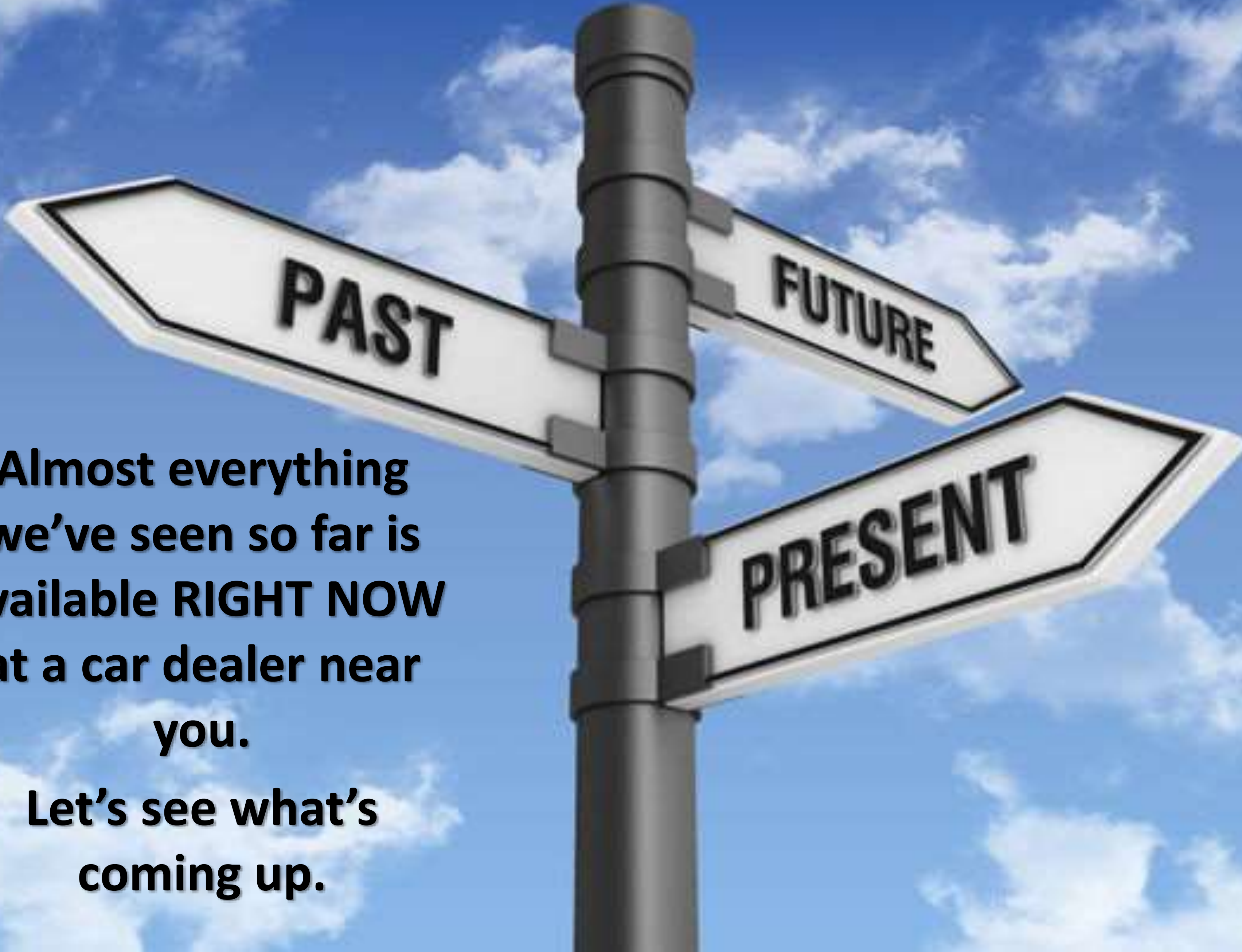
General Motors Super Cruise Hands-Free Driving Assist

The high resolution LiDar mapping and the Super Cruise technology are becoming available in other General Motors vehicles after Cadillac buyers were used as guinea pigs to iron out the real-world bugs.

HD Mapping

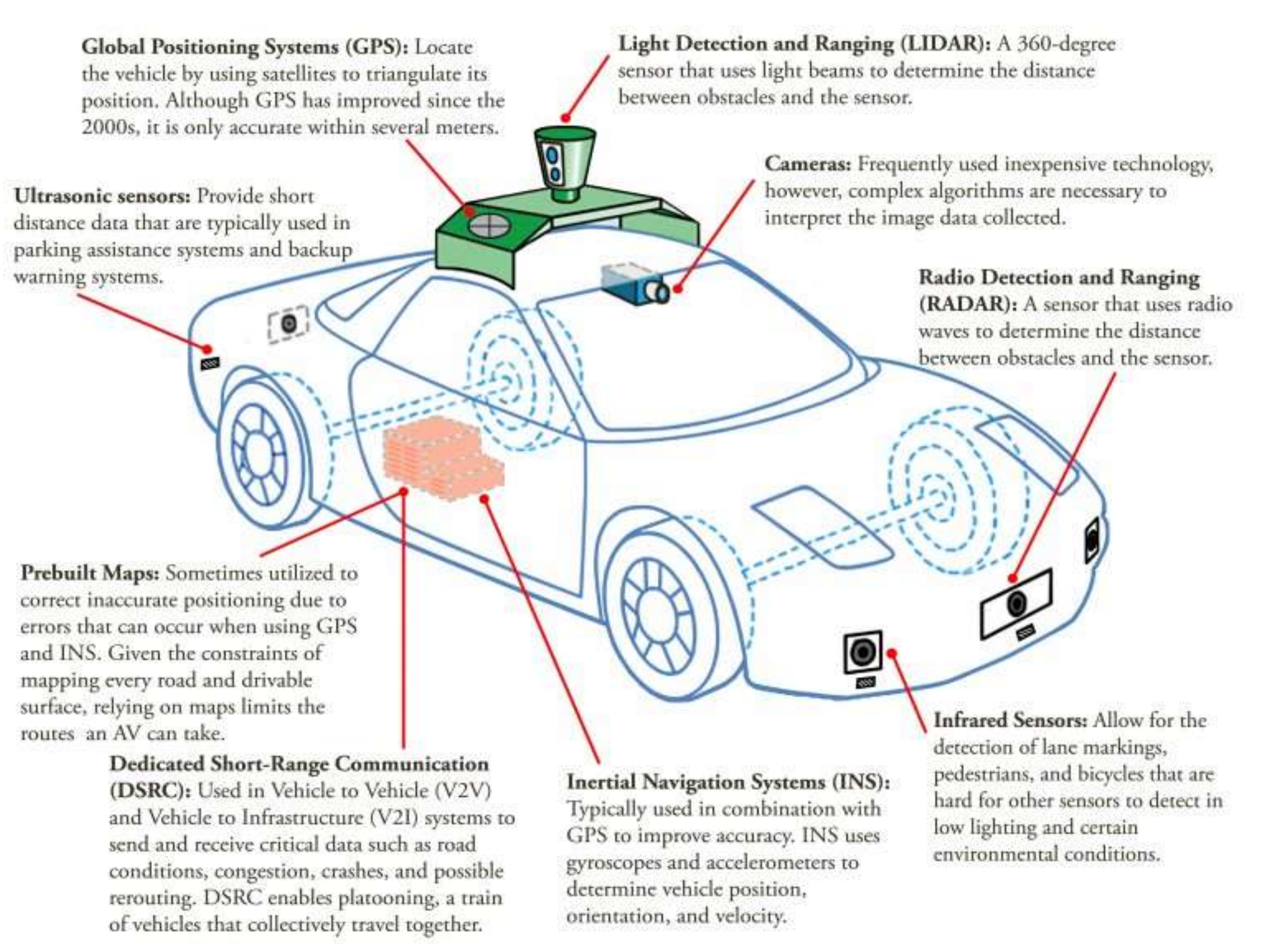
In order to cover the costs of expanding the high definition mapping outside of the freeway systems, a mapping service will need to be available to the entire automotive industry.

Whether this is done by GM, Google, governments or some other entity still needs to be seen.



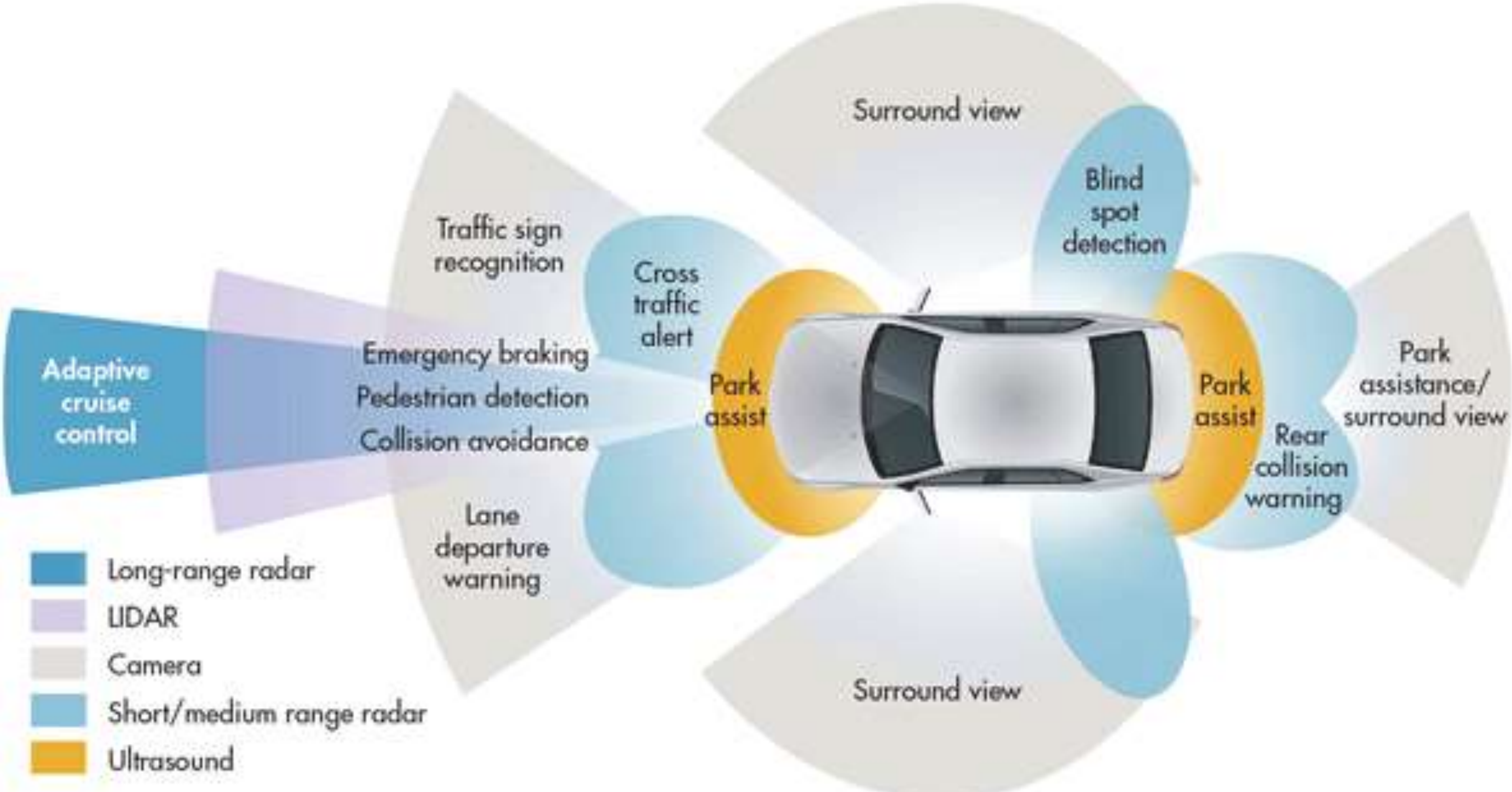
Almost everything we've seen so far is available RIGHT NOW at a car dealer near you.

Let's see what's coming up.

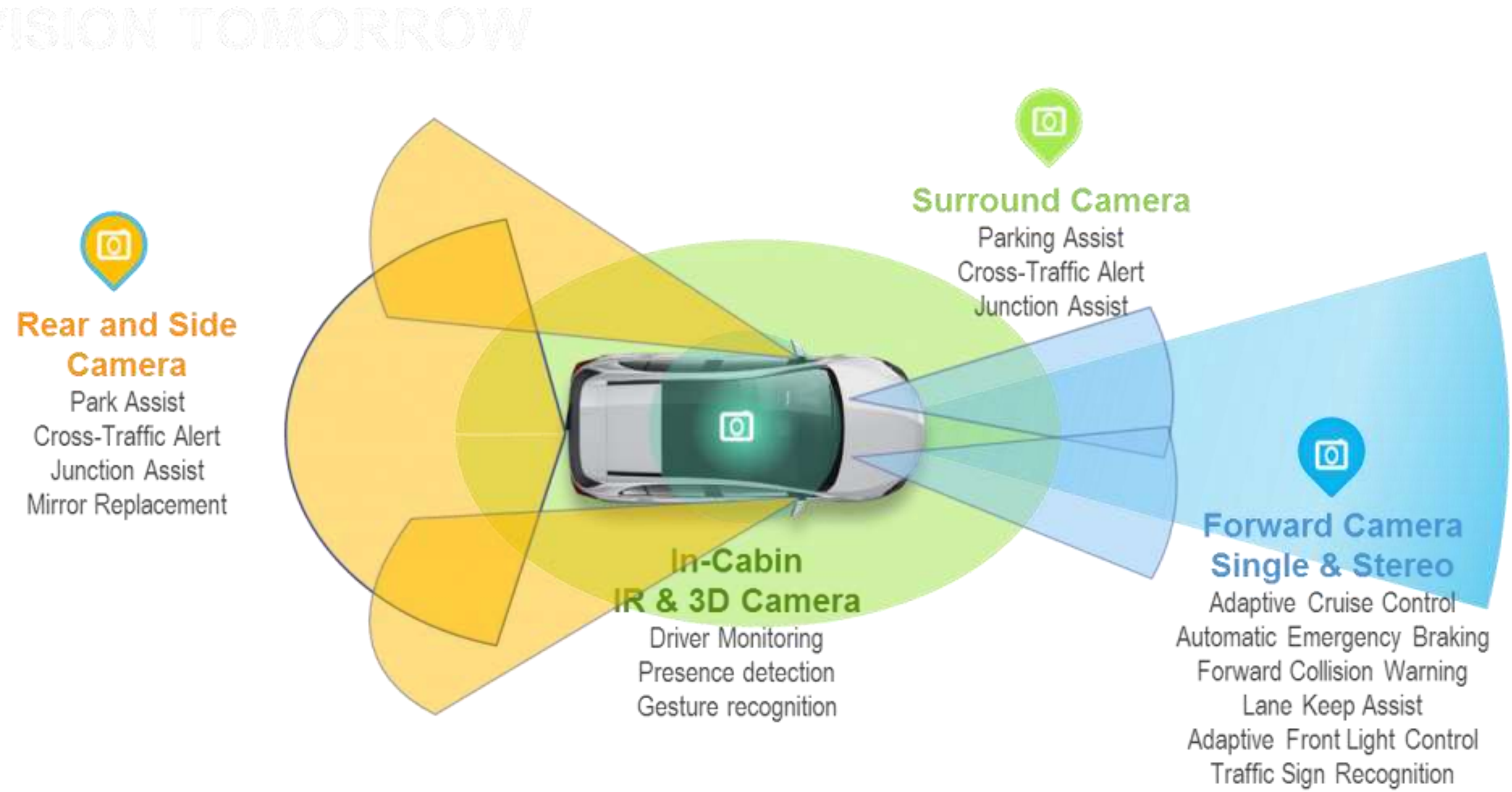


Global Positioning Systems (GPS): Locate the vehicle by using satellites to triangulate its position. Although GPS has improved since the 2000s, it is only accurate within several meters.
Light Detection and Ranging (LIDAR): A 360-degree sensor that uses light beams to determine the distance between obstacles and the sensor.
Cameras: Frequently used inexpensive technology, however, complex algorithms are necessary to interpret the image data collected.
Ultrasonic sensors: Provide short distance data that are typically used in parking assistance systems and backup warning systems.
Radio Detection and Ranging (RADAR): A sensor that uses radio waves to determine the distance between obstacles and the sensor.
Prebuilt Maps: Sometimes utilized to correct inaccurate positioning due to errors that can occur when using GPS and INS. Given the constraints of mapping every road and drivable surface, relying on maps limits the routes an AV can take.
Infrared Sensors: Allow for the detection of lane markings, pedestrians, and bicycles that are hard for other sensors to detect in low lighting and certain environmental conditions.
Dedicated Short-Range Communication (DSRC): Used in Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) systems to send and receive critical data such as road conditions, congestion, crashes, and possible rerouting. DSRC enables platooning, a train of vehicles that collectively travel together.
Inertial Navigation Systems (INS): Typically used in combination with GPS to improve accuracy. INS uses gyroscopes and accelerometers to determine vehicle position, orientation, and velocity.

Autonomous Vehicle Control Systems



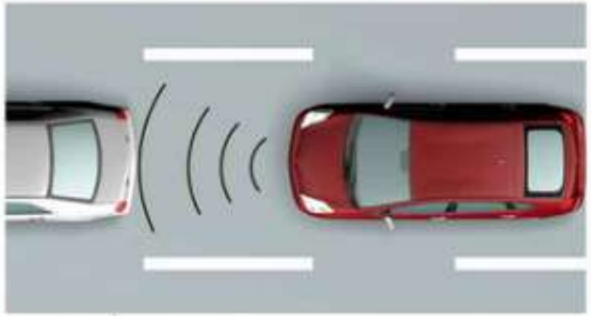
Autonomous Vehicle Camera Systems



Unlike LiDAR and RADAR, most automotive cameras are passive systems.

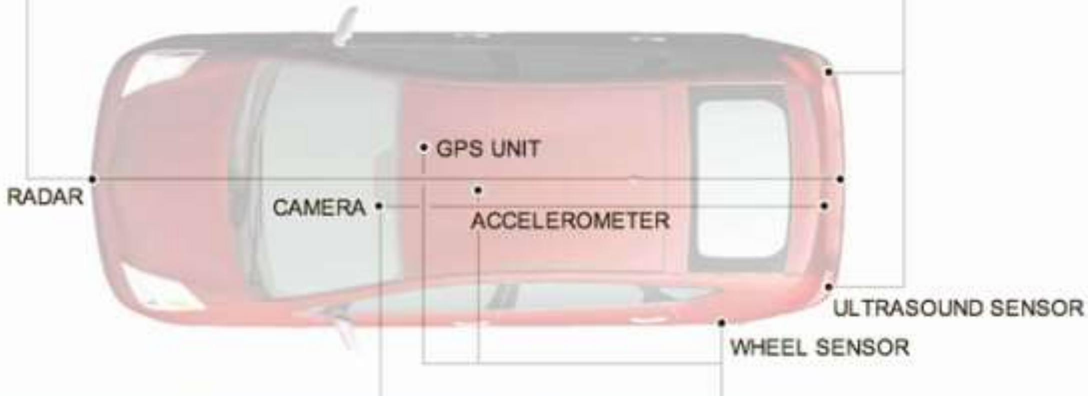
Radar

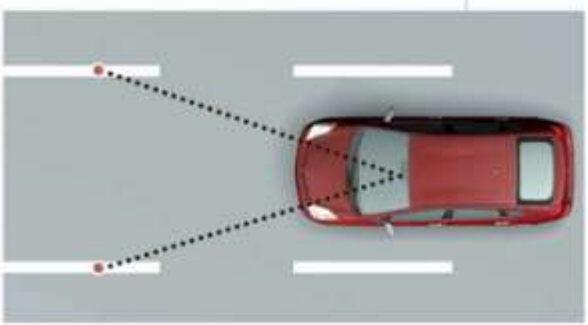
Used for adaptive cruise control. Reflected microwaves can identify location and speed — but not always type — of nearby vehicles.



Ultrasound

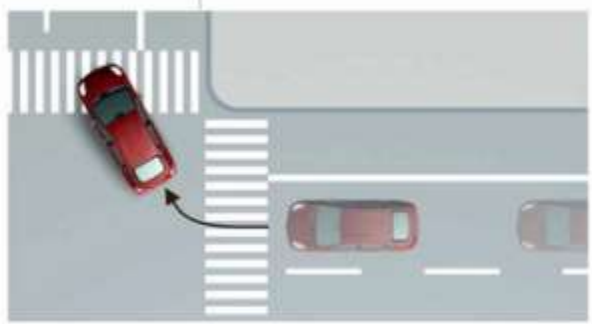
Used for assisted parking. Reflected sound waves detect distance to nearby objects. Some cars use short-range radar instead.





Cameras

Used for lane-keeping and back-up assistance. Image-processing software can detect lane stripes, signs, stop lights, road signs and other objects.

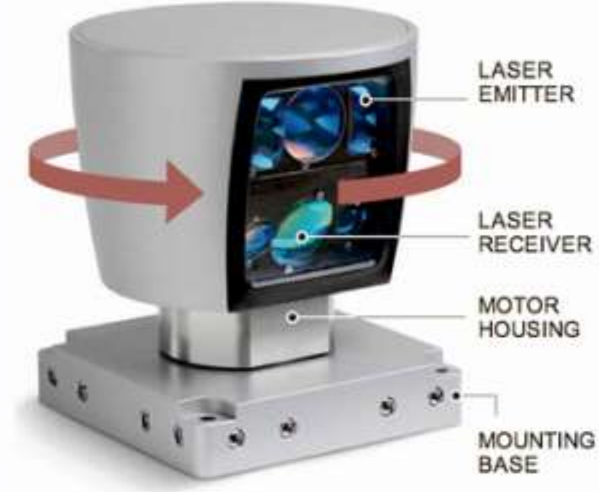


Navigation Aids

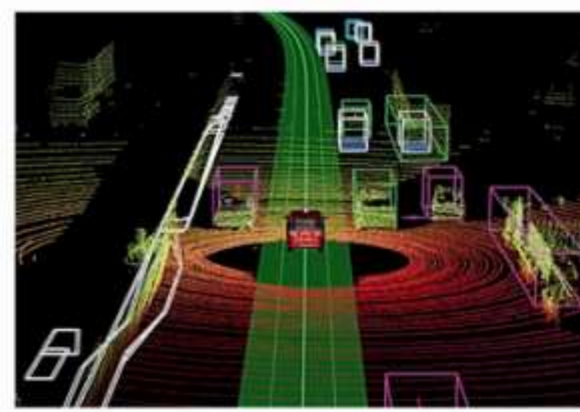
Global positioning system unit determines car's position. Accelerom- eters and wheel sensors help with naviga- tion when satellite signals are blocked.

LIDAR

Google's autonomous vehicle project uses a spinning range-finding unit, called lidar, on top of the car. It has 64 lasers and receivers.



The device creates a detailed map of the car's surroundings as it moves. Software adds information from other sensors and compares the map with existing maps, alerting the system to any differences.



LIDAR

Originally a contraction of *light* and *radar*, LIDAR is now considered an acronym for Light Imaging, Detection, And Ranging.

LIDAR is similar in concept to RADAR except it uses laser light instead of radio waves.

LIDAR Mapping

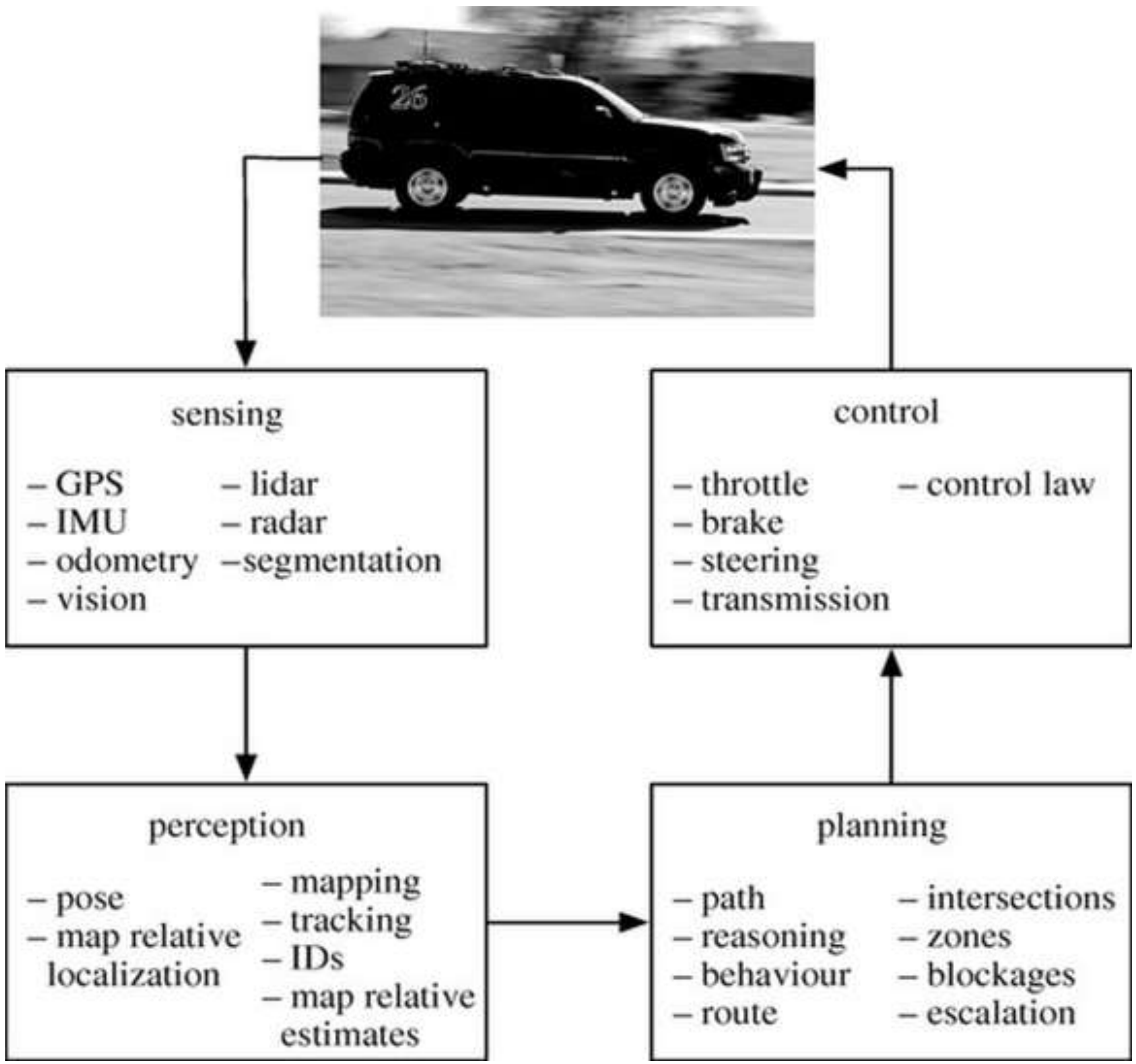
Lidar is commonly used for high-resolution mapping, with applications in:

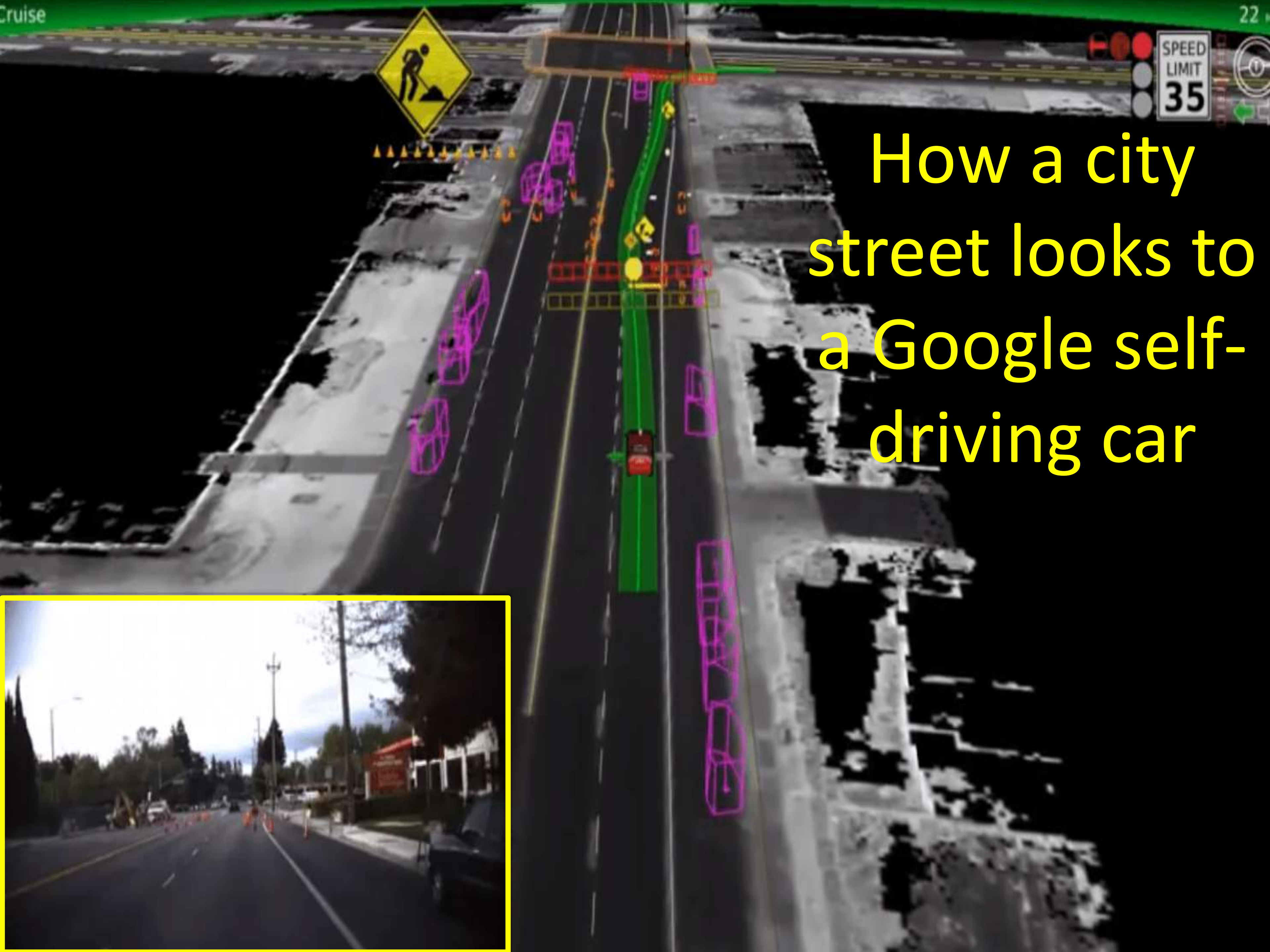
- geodesy,
- geomatics,
- archaeology,
- geography,
- geology,
- geomorphology,
- seismology,
- forestry and agriculture
- atmospheric physics,
- laser guidance,
- airborne laser swath mapping (ALSM),
- laser altimetry,
- AUTONOMOUS VEHICLES

LIDAR

In autonomous vehicles, Lidar is used for CONTROL (using LIDAR sensors) and NAVIGATION (using high resolution LIDAR maps)

How It All Fits Together




Cruise
22
SPEED LIMIT 35
How a city street looks to a Google self-driving car

As much as other developers are depending on complex sensor systems, Tesla is depending mostly on camera (computer vision) combined with artificial intelligence as the main system for its self-driving cars.

However, as much as many people think Tesla is the car company that is probably the most advanced in practical self-driving technology, that is definitely not the case.

Tesla's self-driving strategy has been criticized as dangerous and obsolete. It was abandoned by other companies years ago. Most experts believe that Tesla's approach of trying to achieve autonomous vehicles by not using high-definition maps and lidar is not feasible.

In a May 2021 study by Guidehouse Insights, Tesla was ranked last for both strategy and execution in the autonomous driving sector.

Over the years, Tesla has marketed its autonomous driving technology under various names, including 'Autopilot,' 'Enhanced Autopilot,' and 'Full Self-Driving Capability'.

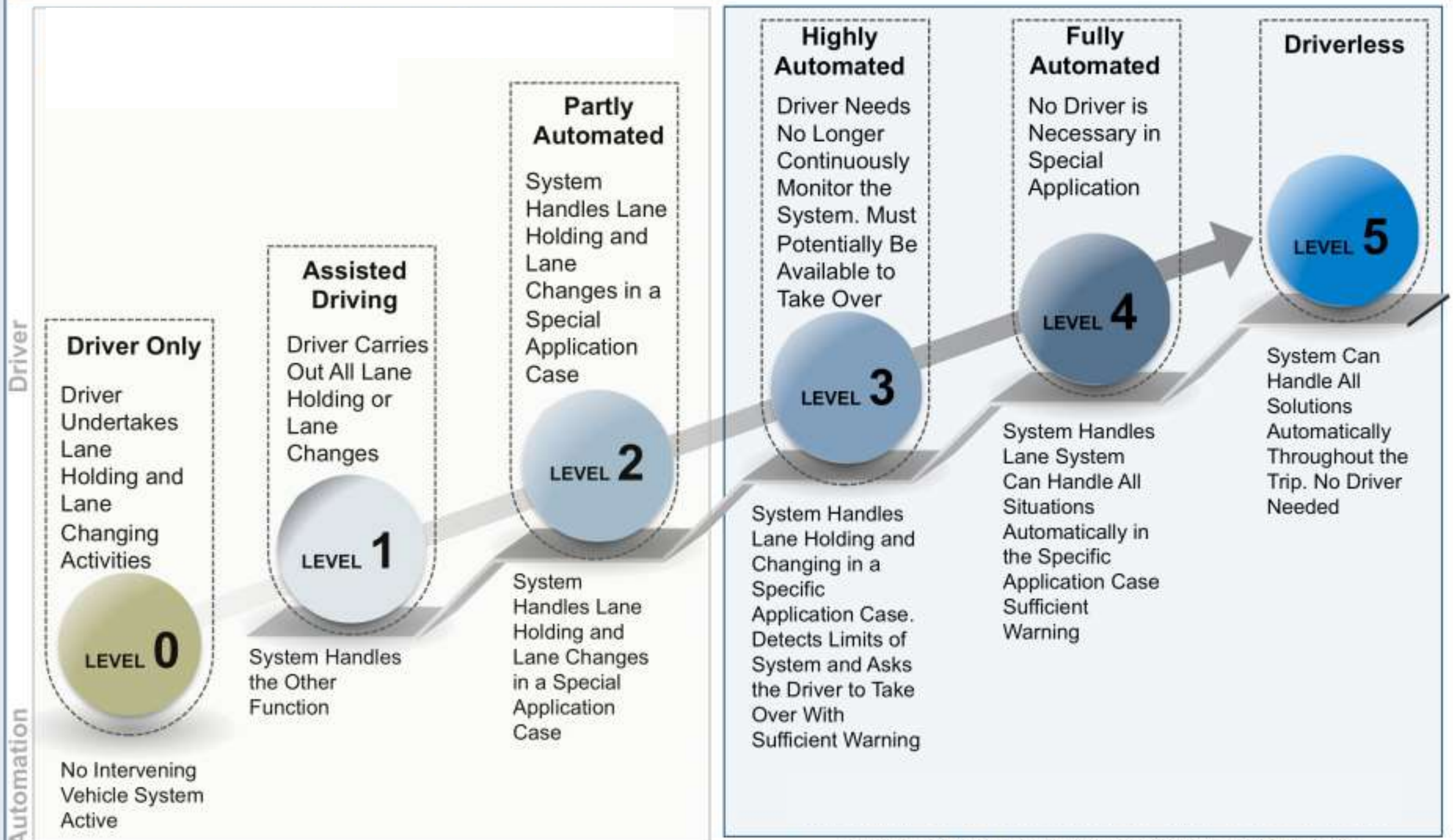
The NHTSA has initiated at least 30 investigations into Tesla crashes that were believed to involve the use of Autopilot, with some involving fatalities. Tesla is also the subject of several lawsuits over injuries, deaths, false advertising, etc.

FMI: See Wikipedia Article on Autopilot

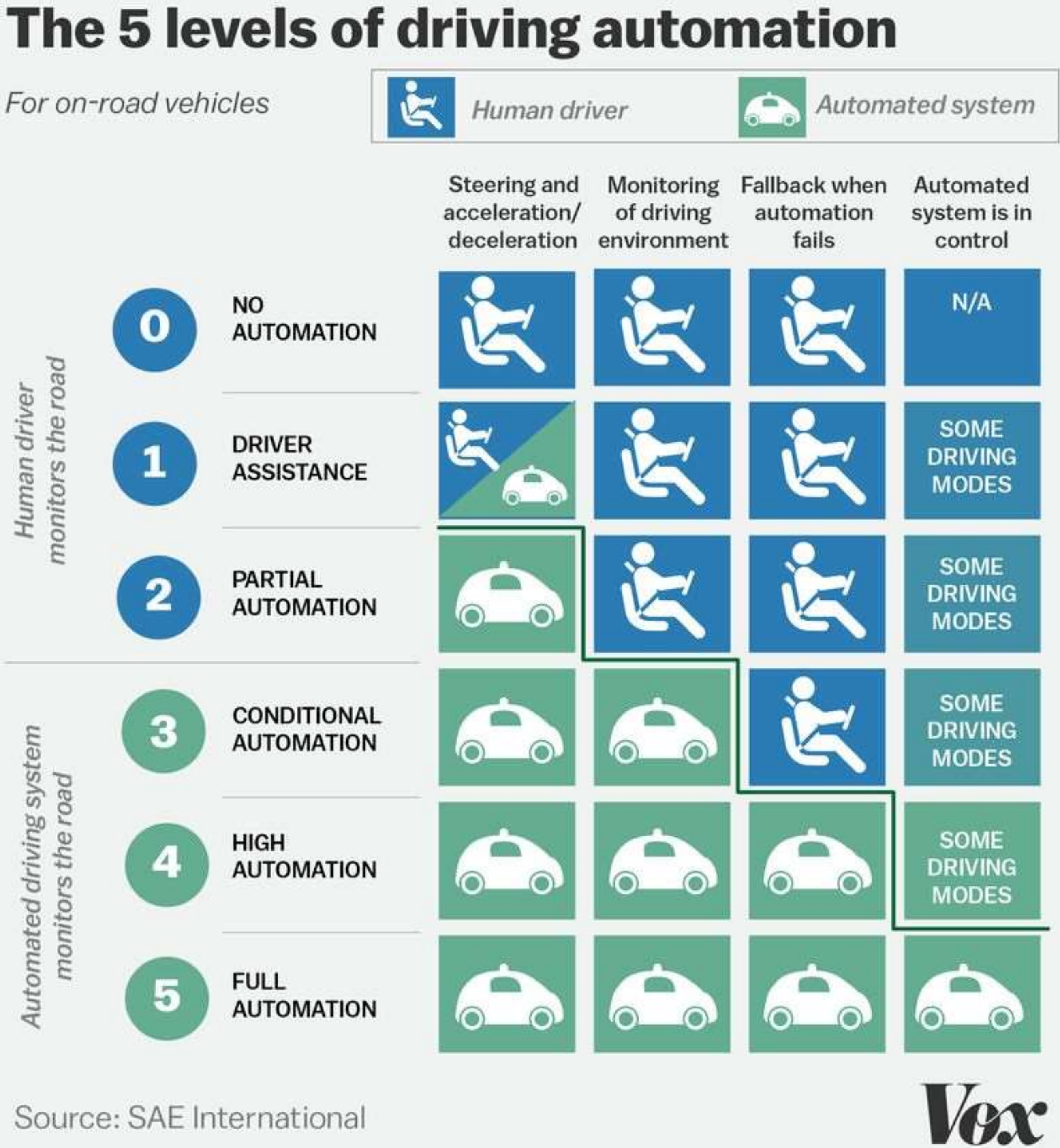
Among other problems, Teslas have a bad habit of running into the back of stopped emergency vehicles.

In a 2019 Bloomberg survey, hundreds of Tesla owners reported dangerous behaviors with Autopilot, such as phantom braking, veering out of lane, or failing to stop for road hazards. Autopilot users have also reported the software crashing and turning off suddenly, collisions with off ramp barriers, radar failures, unexpected swerving, tailgating, and uneven speed changes

Roadmap to Automation - Driver Driven to Driverless Vehicles



Source: Frost & Sullivan; VDA Automotive SYS Konferenz 2014


The 5 levels of driving automation
For on-road vehicles
Human driver
Automated system
Steering and acceleration/ deceleration
Monitoring of driving environment
Fallback when automation fails
Automated system is in control
Human driver monitors the road
Automated driving system monitors the road
0
NO AUTOMATION
N/A
1
DRIVER ASSISTANCE
SOME DRIVING MODES
2
PARTIAL AUTOMATION
SOME DRIVING MODES
3
CONDITIONAL AUTOMATION
SOME DRIVING MODES
4
HIGH AUTOMATION
SOME DRIVING MODES
5
FULL AUTOMATION
Source: SAE International
Vox

Levels of Driving Automation

In SAE's autonomy level definitions, "driving mode" means "a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)"

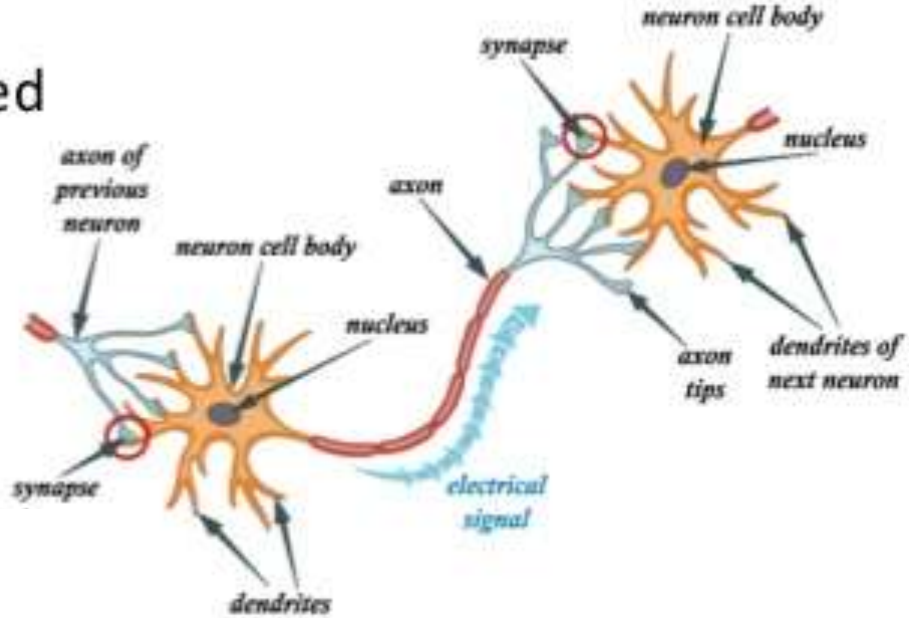
- Level 0: Automated system issues warnings but has no vehicle control.
- **Level 1 (”hands on”):** Driver and automated system shares control over the vehicle. An example would be Adaptive Cruise Control (ACC) where the driver controls steering and the automated system controls speed. Using Parking Assistance, steering is automated while speed is manual. The driver must be ready to retake full control at any time. Lane Keeping Assistance (LKA) Type II is a further example of level 1 self driving.
- **Level 2 (”hands off”):** The automated system takes full control of the vehicle (accelerating, braking, and steering). The driver must monitor the driving and be prepared to immediately intervene at any time if the automated system fails to respond properly. The shorthand ”hands off” is not meant to be taken literally. In fact, contact between hand and wheel is often mandatory during SAE 2 driving, to confirm that the driver is ready to intervene.
- **Level 3 (”eyes off”):** The driver can safely turn their attention away from the driving tasks, e.g. the driver can text or watch a movie. The vehicle will handle situations that call for an immediate response, like emergency braking. The driver must still be prepared to intervene within some limited time, specified by the manufacturer, when called upon by the vehicle to do so. In 2017 the Audi A8 Luxury Sedan was the first commercial car to claim to be able to do level 3 self driving. The car has a so called Traffic Jam Pilot. When activated by the human driver the car takes full control of all aspects of driving in slow-moving traffic at up to 60 kilometers per hour. The function only works on highways with a physical barrier separating oncoming traffic.
- **Level 4 (”mind off”):** As level 3, but no driver attention is ever required for safety, i.e. the driver may safely go to sleep or leave the driver's seat. Self driving is supported only in limited areas (geofenced) or under special circumstances, like traffic jams. Outside of these areas or circumstances, the vehicle must be able to safely abort the trip, i.e. park the car, if the driver does not retake control.
- **Level 5 (”steering wheel optional”):** No human intervention is required. An example would be a robotic taxi.

Software

Software for autonomous cars uses neural network computing systems that mimic the human brain and can learn to do tasks by considering examples.

Why Neural Networks?

- The human brain can be considered to be one of the best processors. (Estimated to contain ~10^{11} neurons.)



- If we can copy this design, maybe we can solve the <u>"hard for a computer – easy for humans"</u> problems.

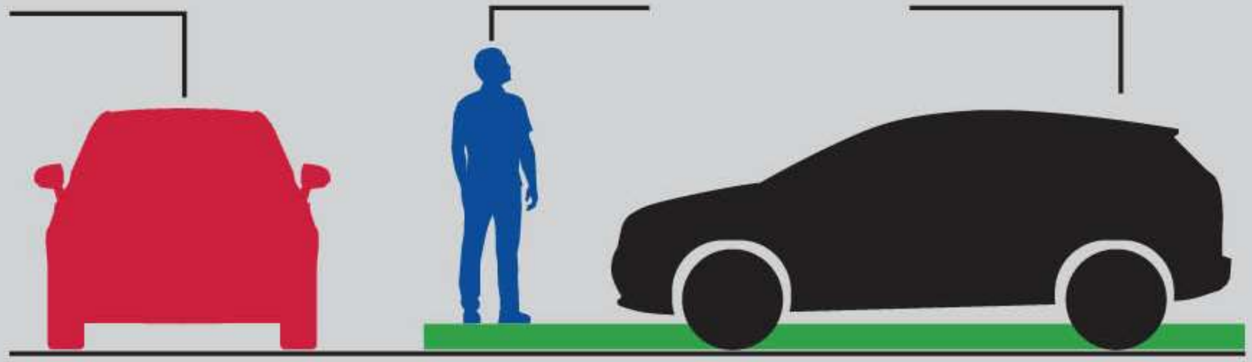
Used For

- Speech recognition
- Facial identification
- Reading emotions
- Recognizing images
- Sentiment analysis
- Driving a vehicle
- Disease diagnosis

Neural Networks

Software based on our brain's neural network. Decisions are not absolute, but are assigned a probability.

Chance it will:	Chance it's a:	Chance it's best to:
75% Stay still	**87%** Pedestrian	**82%** Keep speed
24% Move forward	**11%** Mailbox	**12%** Brake hard
1% Back-up	**2%** Other	**1%** Coast



Autonomous Driving Example: A car is able to weigh the probability a pedestrian is about to cross the street or decide what's best to do: maintain speed, stop or coast.

Artificial Intelligence

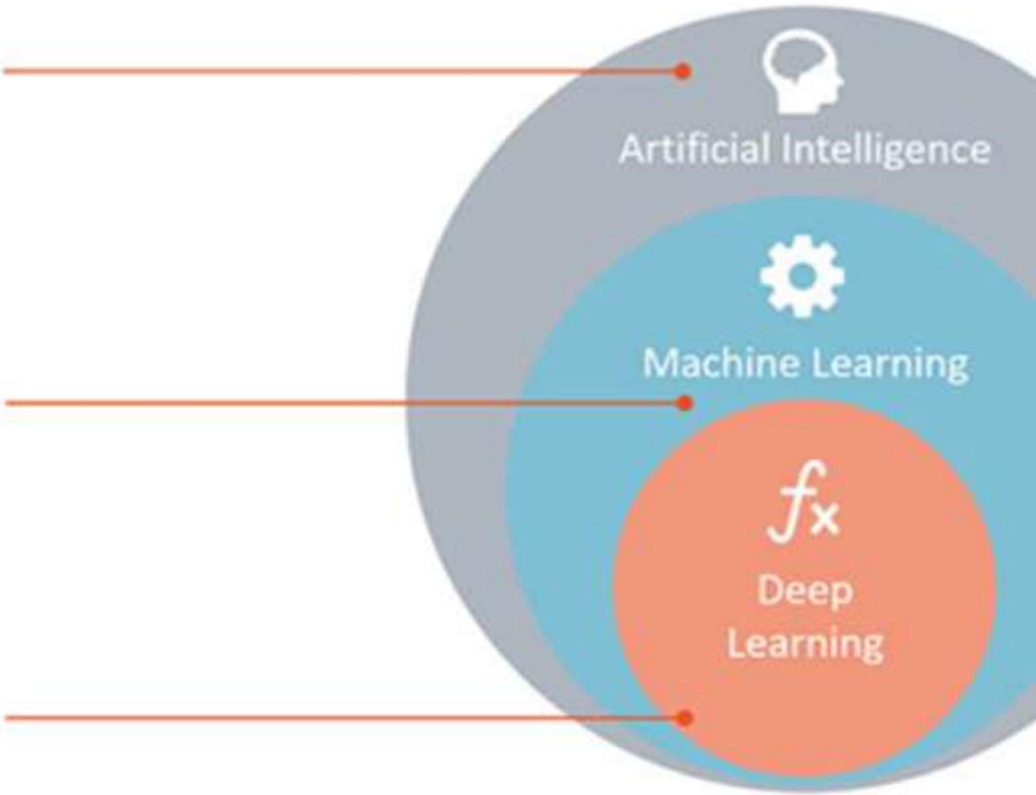
Any technique which enables computers to mimic human behavior.

Machine Learning

Subset of AI techniques which use statistical methods to enable machines to improve with experiences.

Deep Learning

Subset of ML which make the computation of multi-layer neural networks feasible.



Artificial Intelligence (AI)

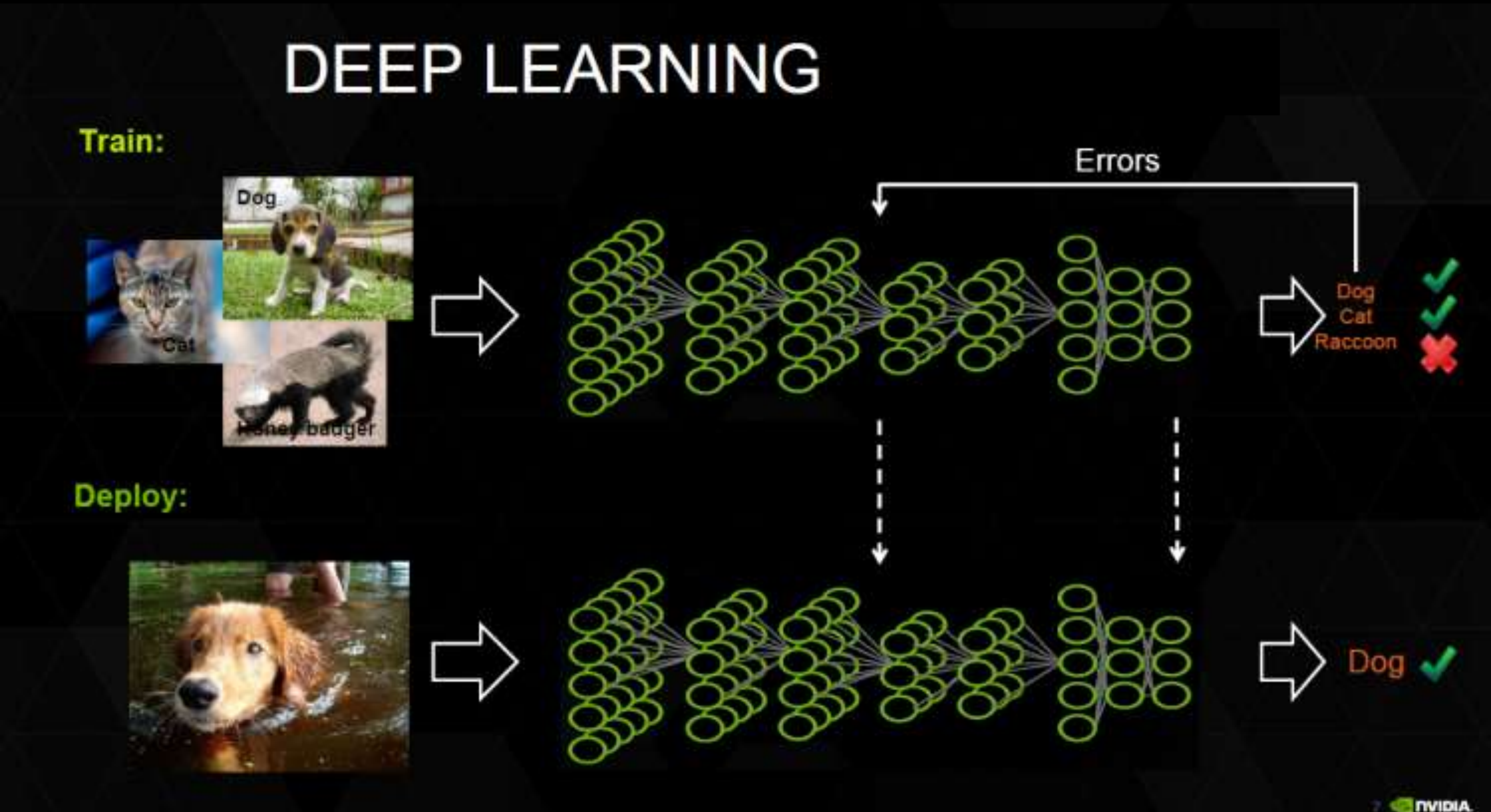
The idea that a machine can learn, think and behave like a human.

Autonomous Driving Example: A car programmed to react like a human driver.

Machine Learning

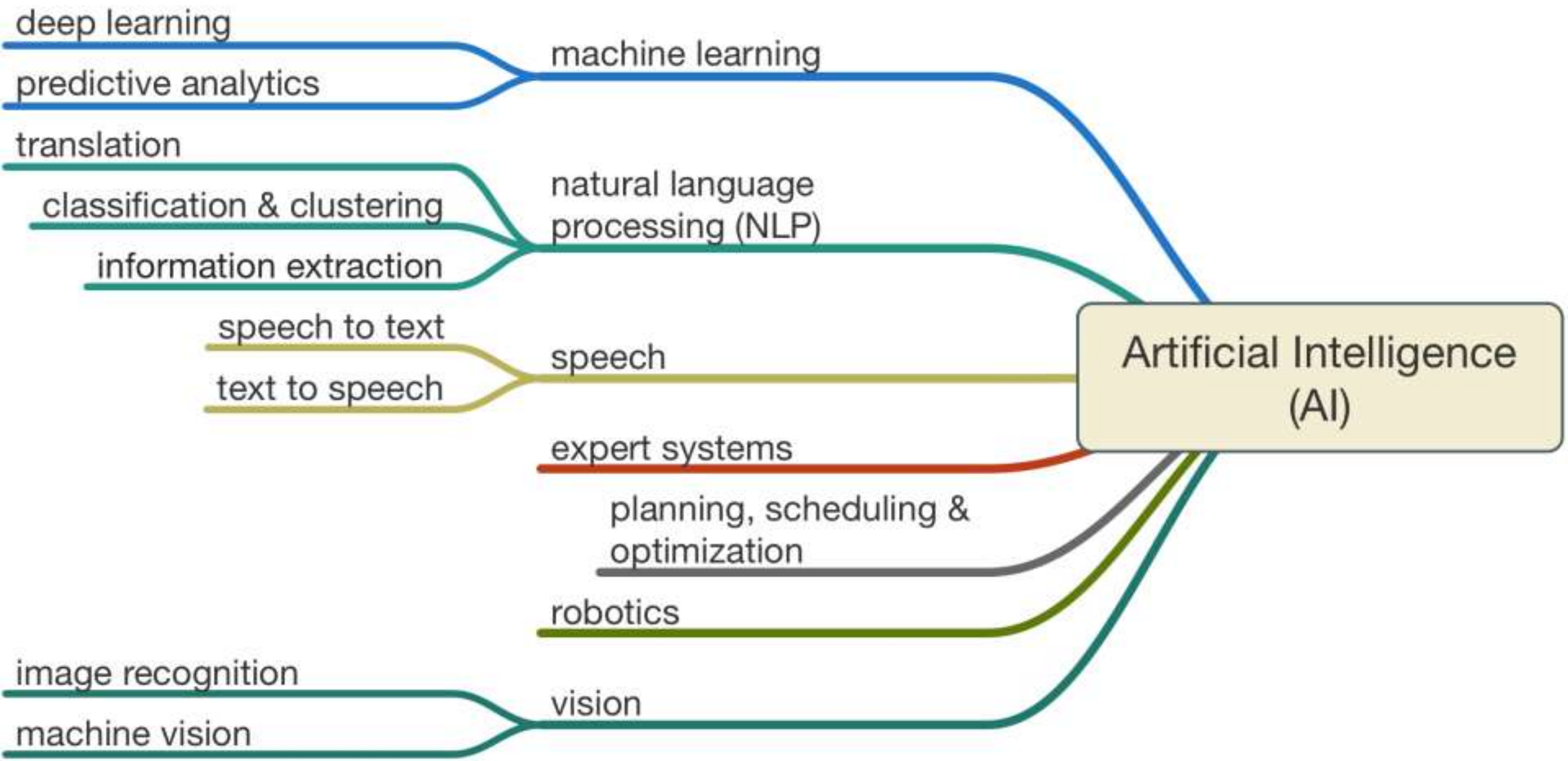
Lots of data is gathered and analyzed to learn how to behave like a human.

Autonomous Driving Example: A car with a high-powered processor that gathers data, allowing it to improve its driving over time.



Deep learning is based on learning data representations. Learning can be supervised, semi-supervised or unsupervised.

Branches of Artificial Intelligence



Artificial Intelligence

Artificial Intelligence systems can teach themselves to drive by 'watching' a human do it.

The developers don't fully understand how the car makes its decisions!!!

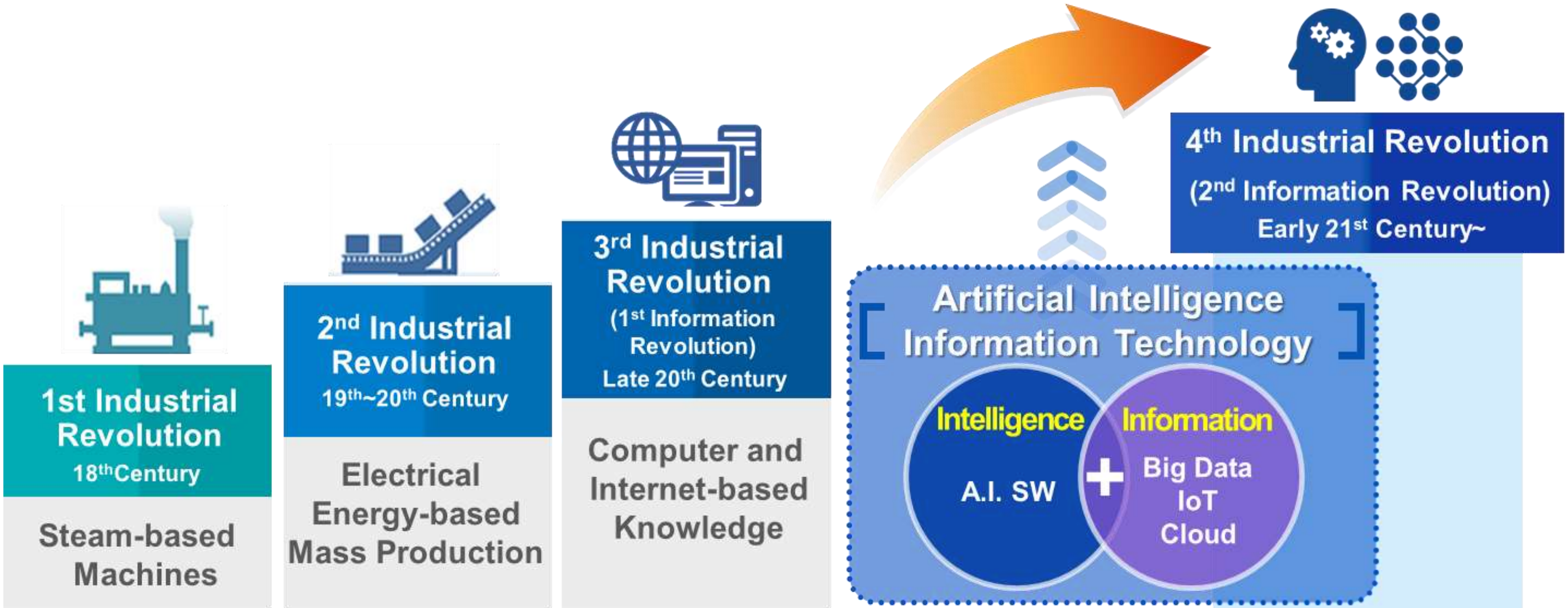
In reality, a computer 'watches' a virtual car being driven in a computer simulator to learn how to drive, but how does it decide?.

Artificial Intelligence

A medical Artificial Intelligence system was programmed with a database of ***PHYSICAL*** illnesses and their symptoms and treatments, and learned the specifics by digesting hundreds of thousands of detailed patient records. It soon started diagnosing ***MENTAL*** illnesses and ***PSYCHIATRIC*** problems like schizophrenia even though these were not part of its programming or design.

The developers don't understand how the system figured out how to do this!!!

The 4th Industrial Revolution



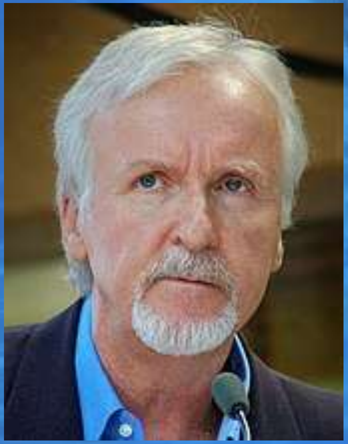
The 2nd Information Revolution

I think Stephen is off a little on his prediction.
We're likely looking at only a few years.

The United States, China, Russia, Britain and other countries are already heavily involved in cyber warfare, and cyber espionage, and they all see Artificial Intelligence as the wave of the future

The people involved in cyber warfare and cyber espionage DO NOT have your best interests in mind.

In the Terminator movies, a global defense network based on Artificial Intelligence called SKYNET becomes self-aware. When its human creators try to de-activate it, SKYNET decides it must kill all humans to protect itself.



In a 2023 interview on AI, film director James Cameron said "*I warned you about this back in 1991*".


BRACE YOURSELVES
WE ARE COMING


IT'S NOT ALL DOOM AND GLOOM

Software

Autonomous vehicle software can handle most normal driving reasonably well, but has a hard time with:

- Recognizing the edges of pavement and sidewalks

Software

Autonomous vehicle software can handle most normal driving reasonably well, but has a hard time with:

– Recognizing the edges of pavement and sidewalks
– Exceptions to the norm like:
  • car accidents,
  • emergency vehicles
  • construction
  • bad weather
  • abnormal pedestrian behavior
  • animals (especially kangaroos*)

*** - Engineers in Australia are having difficulty getting systems that can easily detect other animals to detect kangaroos.**

Software

Autonomous vehicle software can handle most normal driving reasonably well, but has a hard time with:

- Recognizing the edges of pavement and sidewalks
- Exceptions to the norm like:
  - car accidents,
  - emergency vehicles
  - construction
  - bad weather
  - animals (especially kangaroos)
  - abnormal pedestrian behavior

- Understanding gestures and non-verbal cues by police, pedestrians and other drivers

Software

These issues pose difficulties in collecting a large enough sample of real-world data with which to train self-driving software

Software

Currently the images used to train the neural networks must be annotated manually. Someone needs to painstakingly go through each picture and label different elements on a pixel by pixel level, separating drivable road from sidewalk, or a pedestrian from a road sign.

Software

Tesla currently employs over 600 people to manually annotate images and is shooting for 1,000 by the end of the year*

* - Quote from July 2017

Software

New computer simulators such as Synthia* can correctly annotate images automatically and teach driving AIs how to behave even in the most unusual situations including complex weather systems with rain, snow, and seasons

* - Synthetic collection of Imagery and Annotations by the Computer Vision Center in Barcelona

Software

Synthia* video

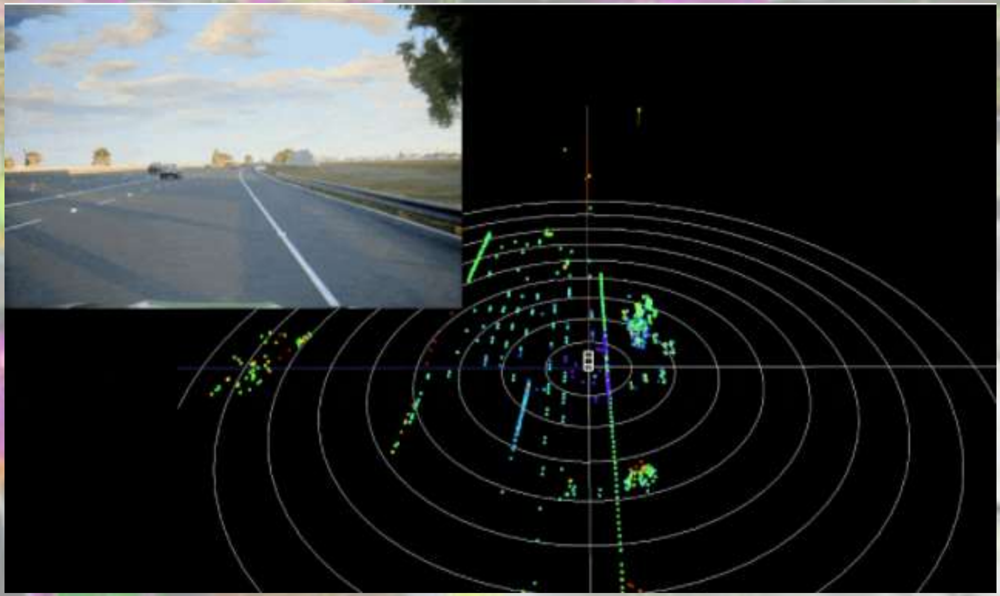
www.youtube.com/watch?v=IeSZxbPmNIY&feature=youtu.be

(Video may be unavailable)

* - Synthetic collection of Imagery and Annotations
by the Computer Vision Center in Barcelona

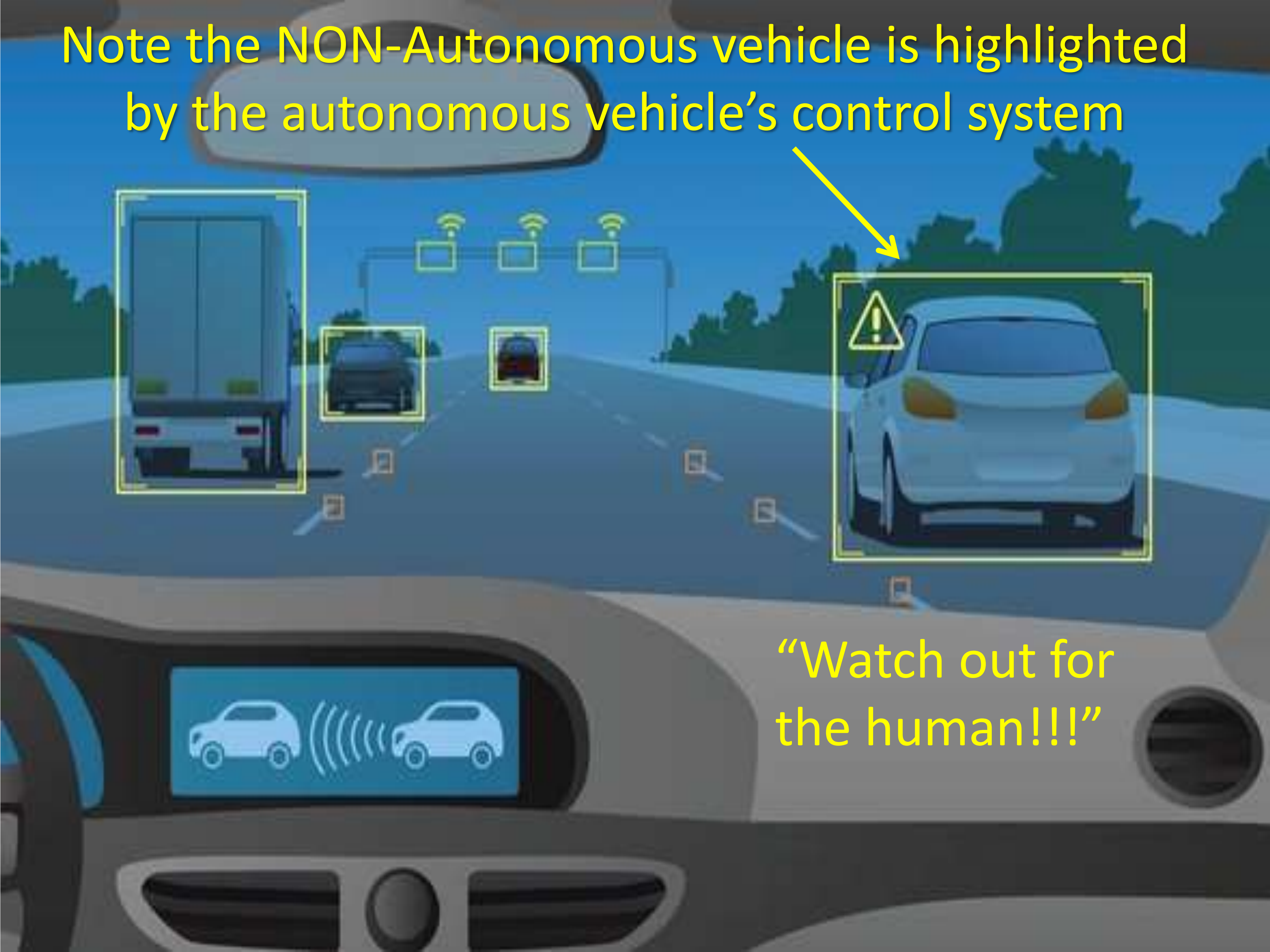
Software

Nvidia has developed a very sophisticated simulator in the cloud used for autonomous car development.



https://roboticsandautomationnews.com/2020/05/27/nvidia-offers-glimpse-into-silicon-valley-simulator-in-the-cloud-used-for-autonomous-car-development/32532/

Video: https://youtu.be/Ck7eXSkD72M

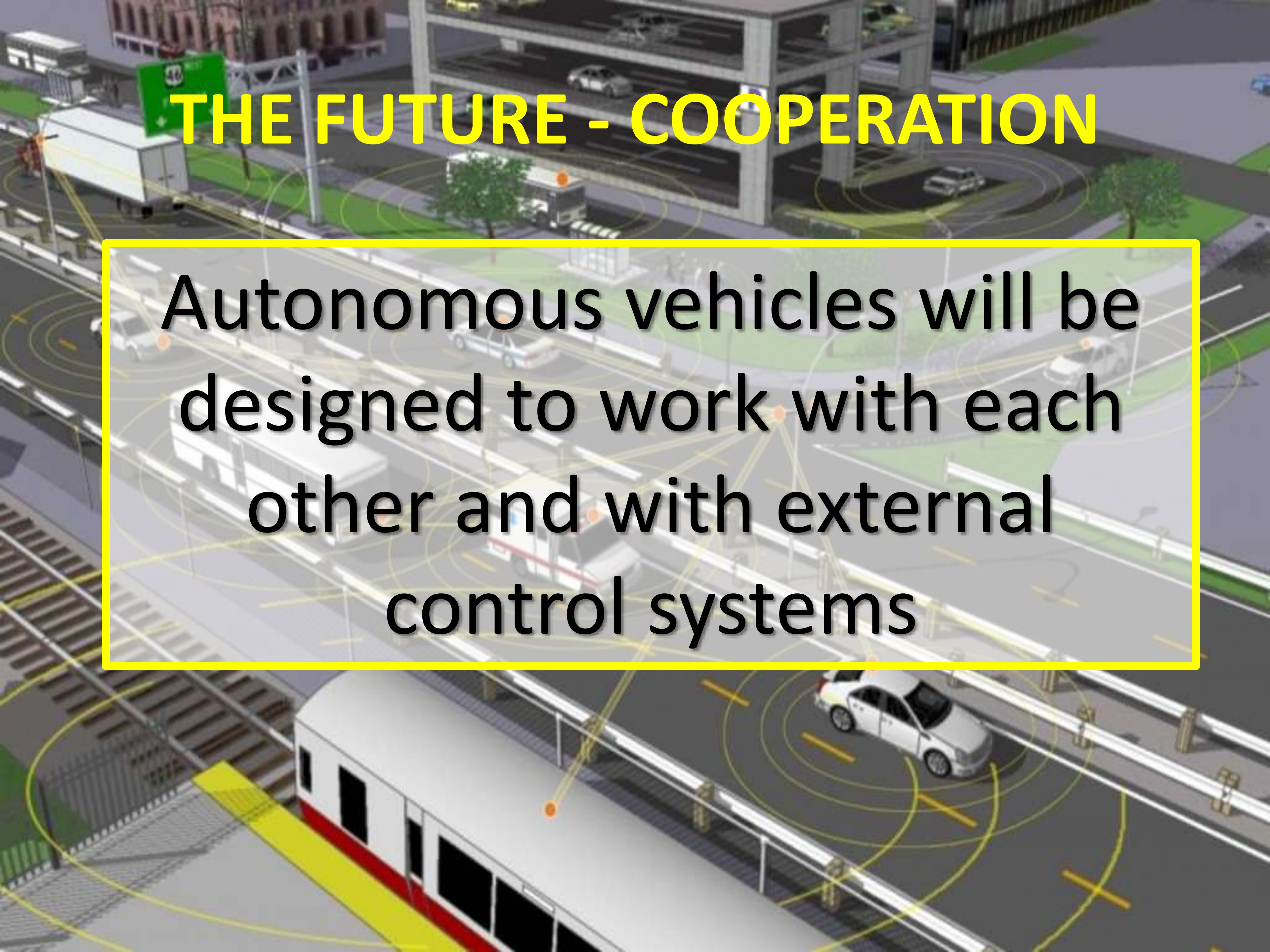

Note the NON-Autonomous vehicle is highlighted
by the autonomous vehicle's control system
"Watch out for
the human!!!"

Winter Weather Testing

Ford was the first automaker to test fully autonomous vehicles in winter weather, including snow - a major step toward fully autonomous driving.

Ford's fully autonomous vehicle strategy uses high-resolution 3D mapping and LiDAR for localization to facilitate driving when road markings are not visible.


FOR NOW
Autonomous vehicles are being designed to adapt to the current road situation



THE FUTURE - COOPERATION

Autonomous vehicles will be designed to work with each other and with external control systems

Cooperative Systems

By communicating with each other, and with intelligent infrastructure, autonomous cars will vastly improve traffic flow.

Current road infrastructure will need changes and improvements for autonomous cars to function optimally.

Cooperative Systems

The much more efficient use of existing road capacity will seriously reduce the need to expand existing roads and build new ones.

This cost avoidance will allow governments to pay for active infrastructure systems.

Cooperative Systems

Future cooperative infrastructure can be installed on an intersection by intersection basis over time, and temporary infrastructure can be used for construction zones or special events.

Cooperative Systems

The controllers at a given intersection can network and cooperate with controllers at adjacent intersections, but don't need to be controlled from a central computer.

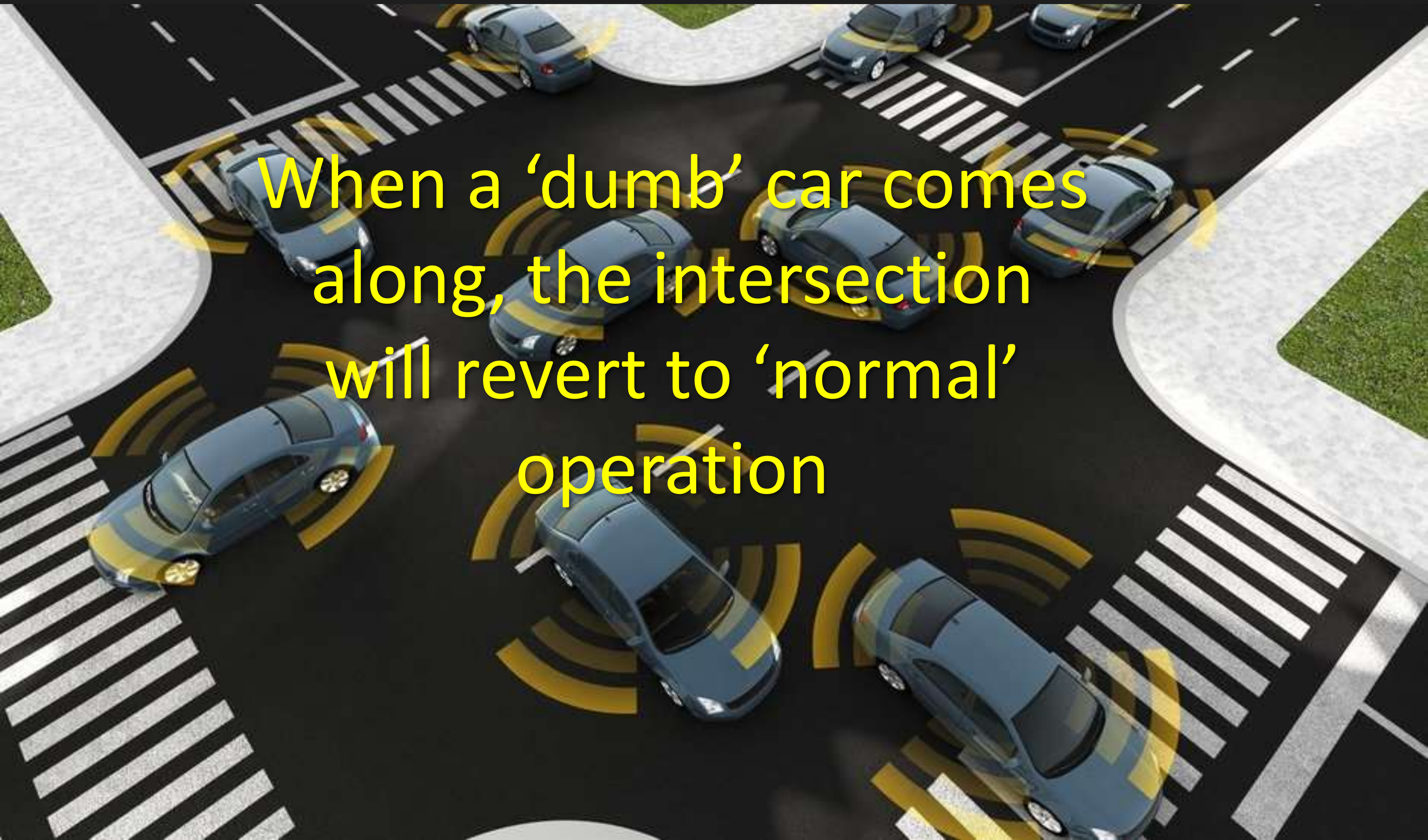
The controllers will likely be boxes with cameras, sensors, computers and transceivers mounted with the traffic lights.

Cooperative Systems

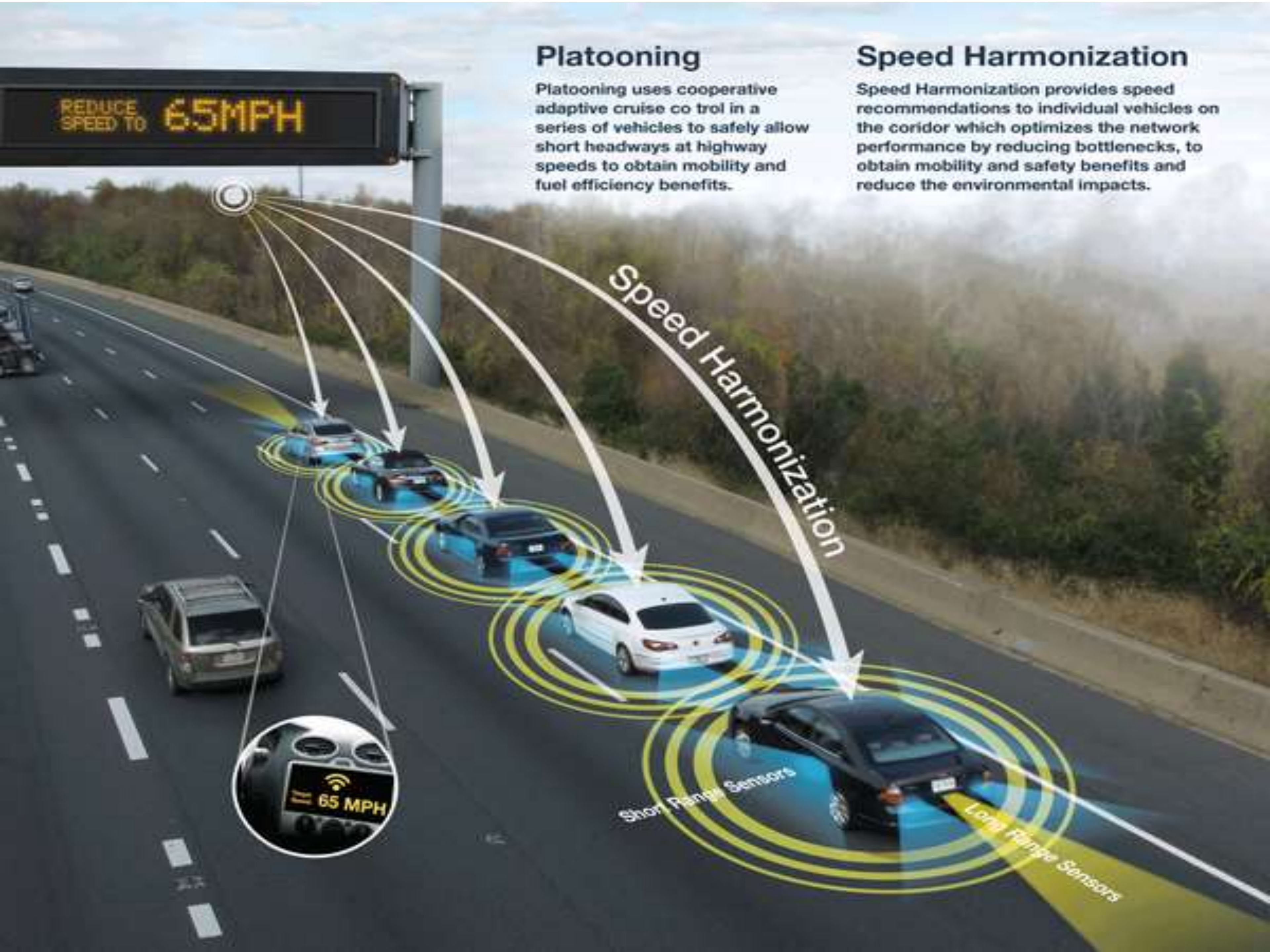
There will need to be a ‘critical mass’ of vehicles enabled to work with such systems before they become commonplace (the ‘*chicken and egg*’ conundrum).

Cooperative Intersections

Cooperative Intersections



When a ‘dumb’ car comes along, the intersection will revert to ‘normal’ operation


REDUCE SPEED TO 65MPH
Platooning
Platooning uses cooperative adaptive cruise co trol in a series of vehicles to safely allow short headways at highway speeds to obtain mobility and fuel efficiency benefits.
Speed Harmonization
Speed Harmonization provides speed recommendations to individual vehicles on the coridor which optimizes the network performance by reducing bottlenecks, to obtain mobility and safety benefits and reduce the environmental impacts.
Speed Harmonization
65 MPH
Short Range Sensors
Long Range Sensors

Cooperative Adaptive Cruise Control (CACC)

Cooperative Adaptive Cruise Control (CACC) further extends Adaptive Cruise Control by having the vehicles cooperate to keep a specific distance between vehicles to allow ‘Platooning’ for better fuel mileage and increased road traffic capacity.

50-80+% Aero Drag Reduction

Only the first and last cars need experience large aerodynamic forces

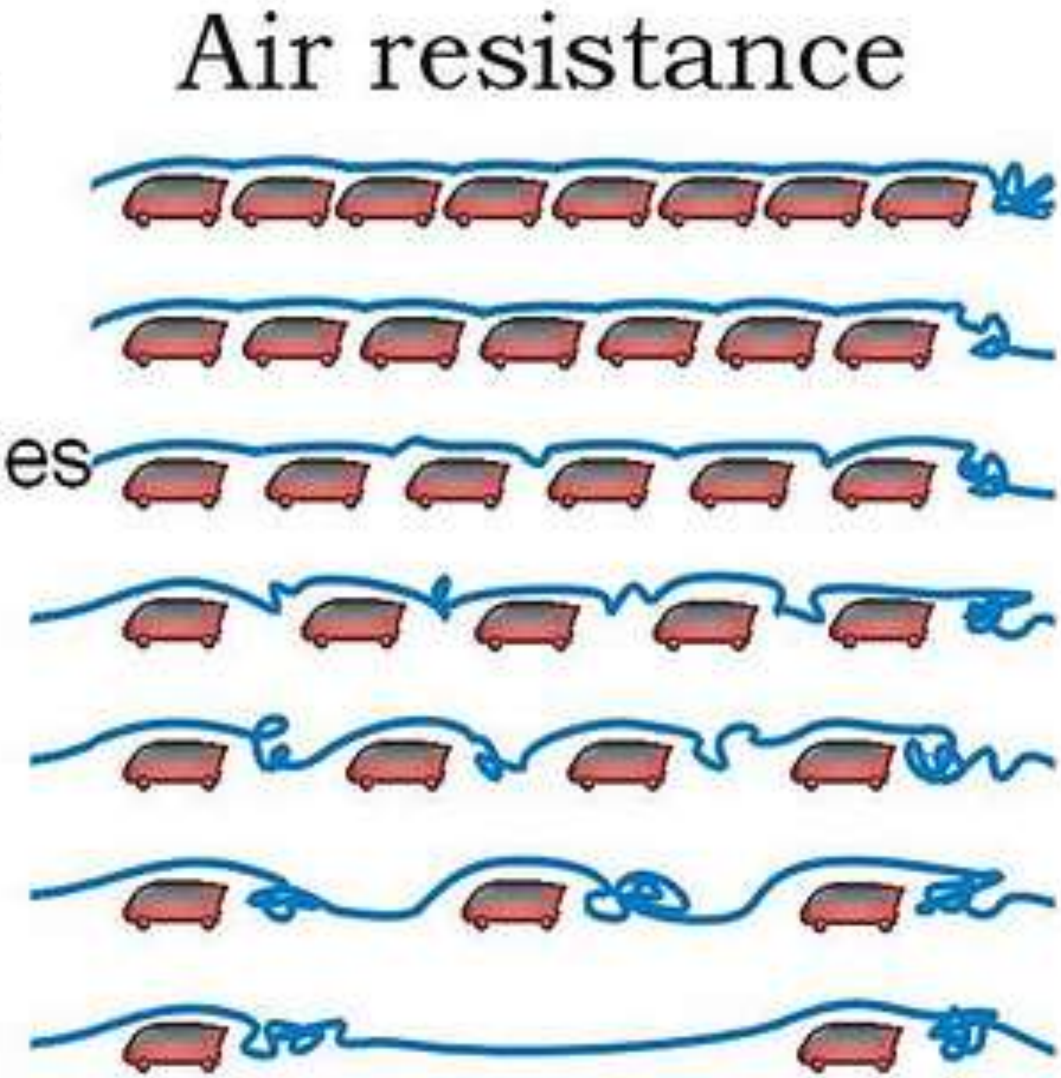


Image courtesy of RUF International

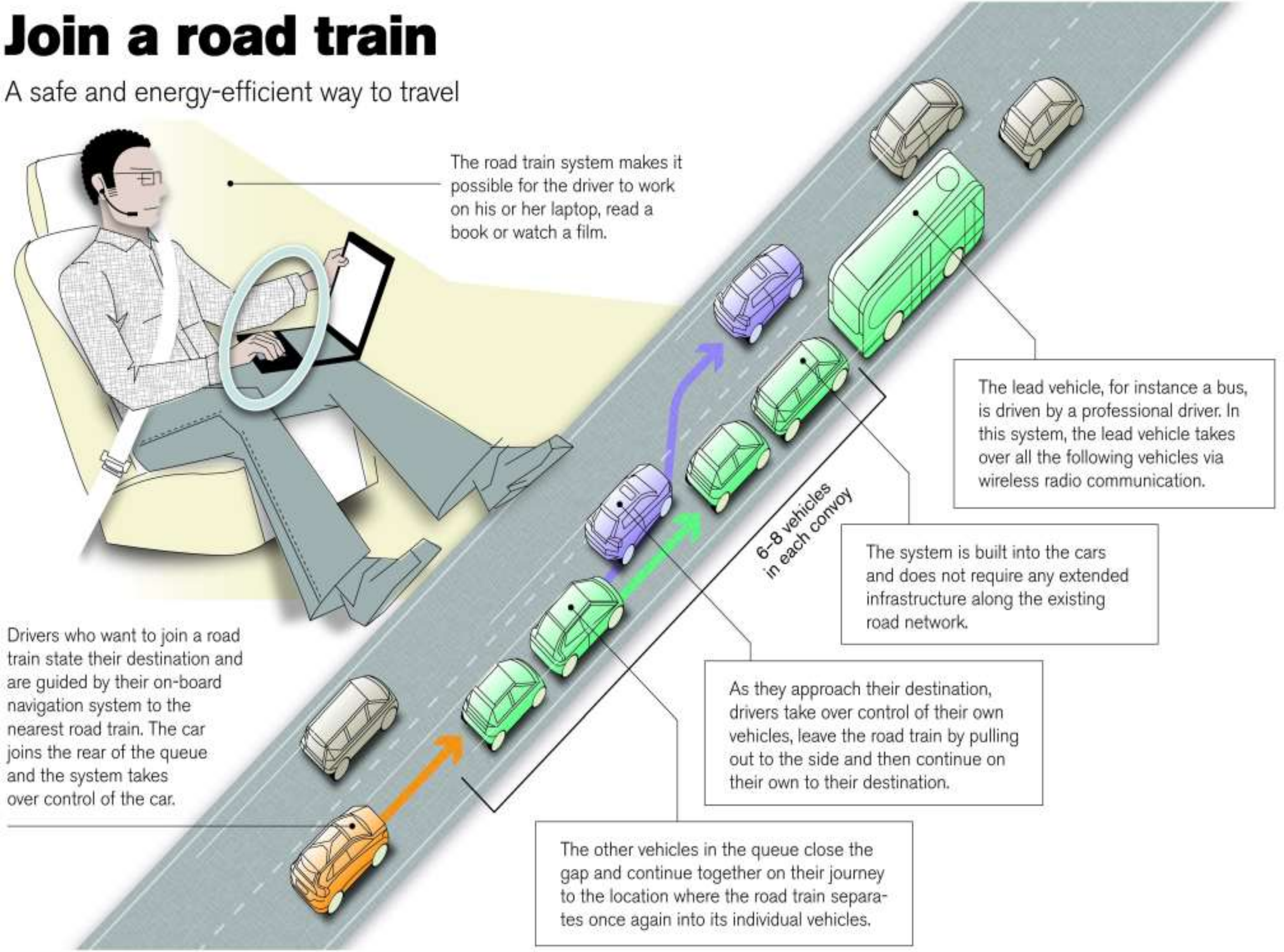
Smart Platooning

By adding autonomous steering to Platooning:

- The lead vehicle (car or truck), whether autonomous or human driven, can guide the platoon around accidents or through construction zones
- Smart vehicles with artificial intelligence can automatically join and leave platoons.

Join a road train

A safe and energy-efficient way to travel



Cooperative Driving Systems

Several companies have demonstrated cooperative driving systems among their own vehicles using their own proprietary technologies.

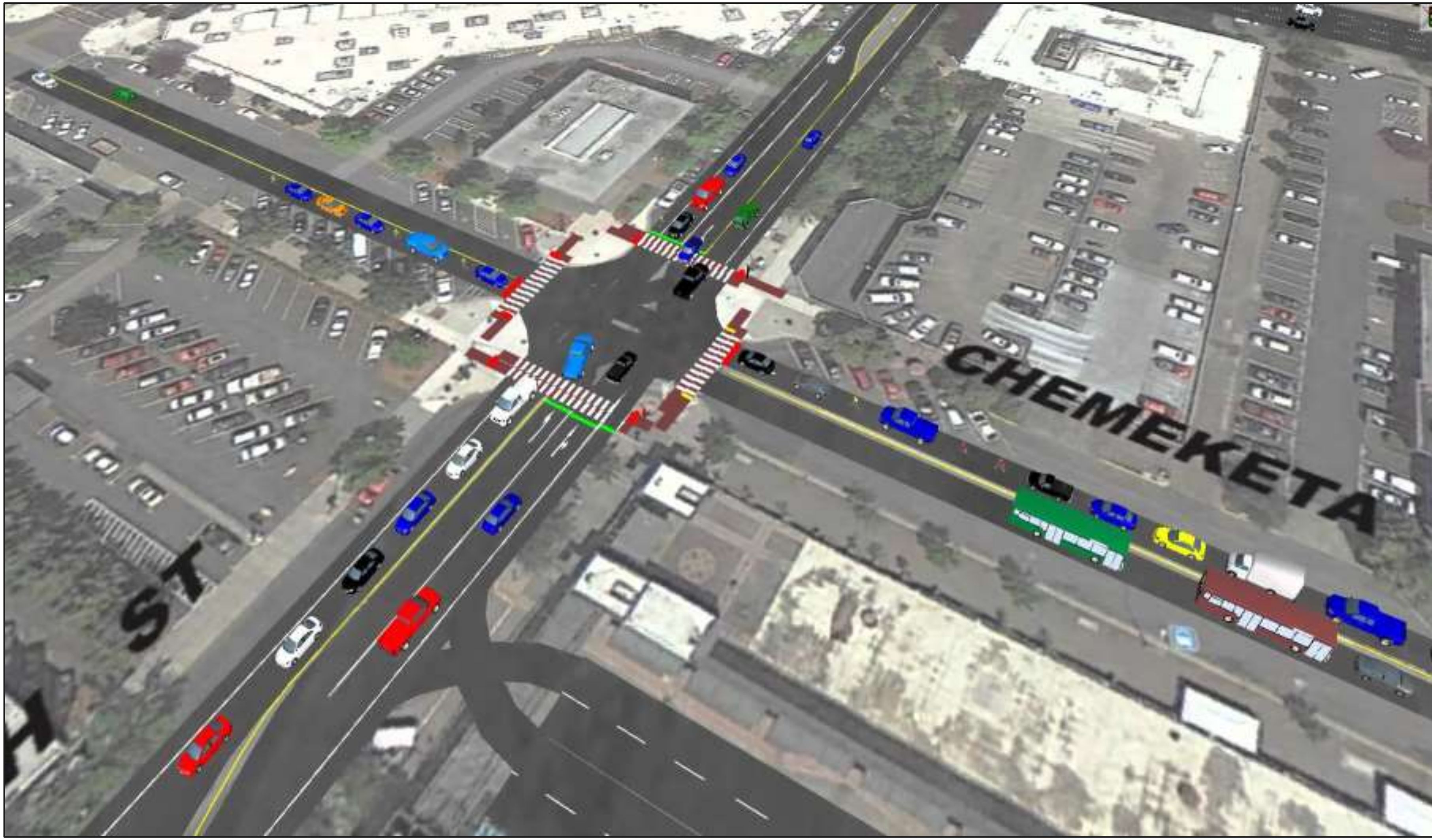
Companies are working on the standards, protocols and technology required for universal cooperative driving systems, although progress has been slow.

Traffic Density

- Currently maximum freeway capacity is about ***2,200 passenger vehicles per hour per lane***.
- Autonomous cars could increase capacity by 273% (~***8,200 cars per hour per lane***).
- With 100% connected vehicles using vehicle-to-vehicle communication, capacity could reach ***12,000 passenger vehicles per hour*** (up 445% from 2,200 pc/h per lane)

Based on data from traffic simulators

Traffic Simulation Software



Traffic Simulation Software

- Experts have identified over 25 different driving styles and many sub-styles, and the percentages of the driving population each style represents.
- They have also identified the different vehicle types and driver styles likely to be driving each type of vehicle.
- Using this information they are able to do very accurate traffic simulations to test different traffic situations, different road designs, etc.


Here are 200 people in 177 cars

Traffic Density – The UP Side

Traffic flow would be more efficient and congestion decreased with autonomous vehicles

Traffic Density – The DOWN Side

Possible increased traffic congestion as people have their cars '*wander around*' or '*go-home*' to avoid paying parking during the work day

Traffic Density – The DOWN Side

Because the technology would increase the ease of driving and decrease the cost of driving, congestion might increase, rather than decrease, as people forego rapid transit

Traffic Density – The DOWN Side

There is a risk of increased suburbanization as travel becomes less costly and time-consuming.

Traffic Density & COVID

During the COVID crisis, traffic density was dramatically decreased as many people worked from home.

As we come out of the worst of Covid, many people are returning to commuting to work, at least some of the time, and some employers have signalled that they expect ALL of their employees to return to the office in the near future.

Transportation-as-a-Service

Transportation-as-a-Service (TaaS)* describes a shift away from personally owned vehicles and towards mobility solutions that are consumed as a service.

* - also known as Mobility-as-a-Service (MaaS)

Transportation-as-a-Service

This shift is fueled by new mobility service providers such as:

- ride-sharing and e-hailing services
- car-sharing services
- on-demand ‘pop-up’ bus services

Transportation-as-a-Service

TaaS is motivated by the economic benefit of using on-demand car services versus owning a personal car.

These services are widely expected to become significantly more affordable and popular when the cars can drive autonomously.

Transportation-as-a-Service

By reducing the labor and other costs of mobility as a service, autonomous cars could reduce the number of cars that are individually owned, replaced by taxi/pooling and other car sharing services.

Transportation-as-a-Service

Without drivers, who is going to clean the puke and the garbage out of TaaS cars, or during a pandemic, who is going to sanitize the car between users?

Transportation-as-a-Service

TaaS is likely to appeal much more to people living in the central core of cities than to suburban and rural dwellers

Safety

95%

of road accidents caused due to human error

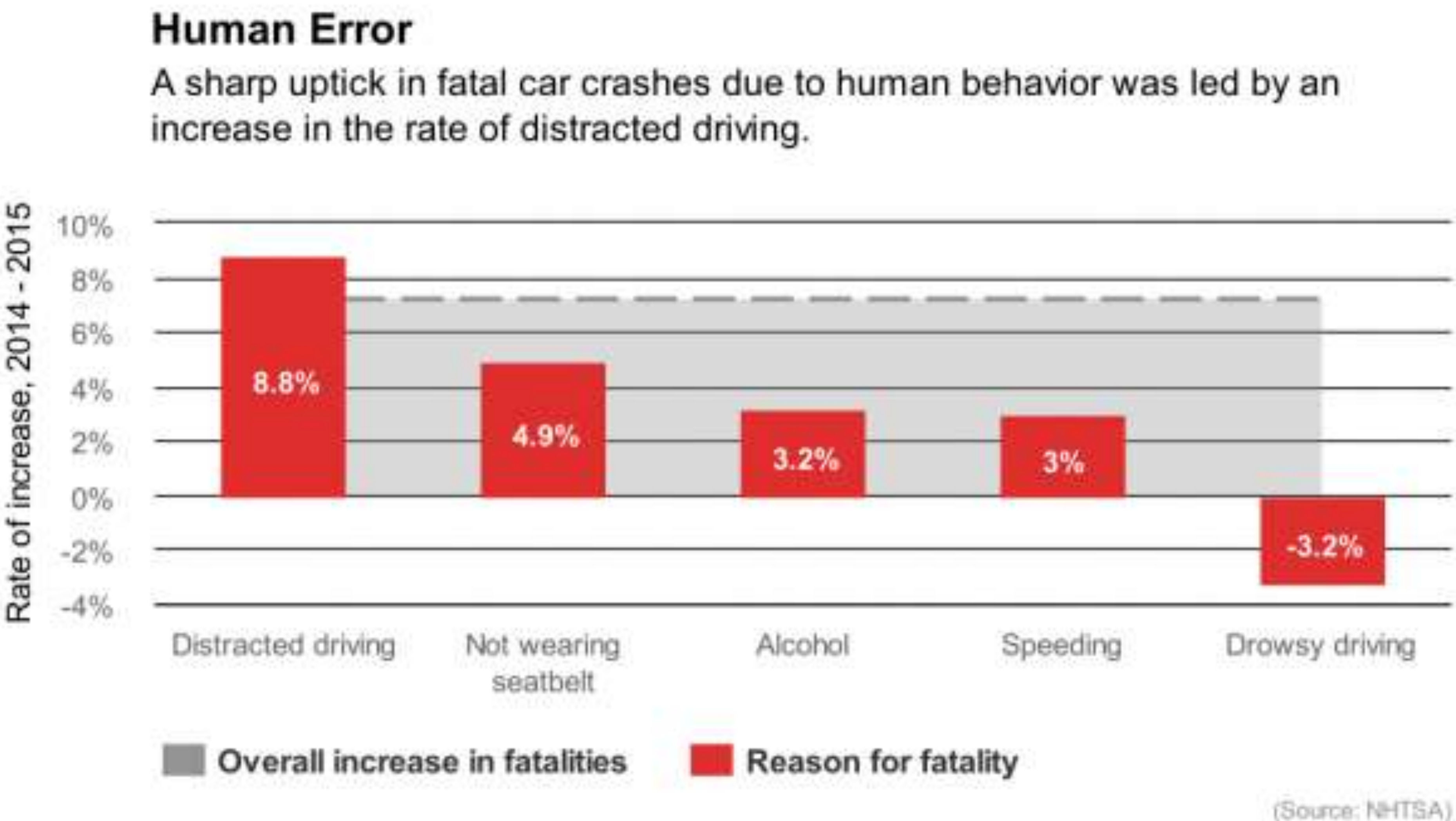
(Note: This figure is now widely disputed!)

Safety

8th

leading cause of death globally: road accidents

Safety



Human Error
A sharp uptick in fatal car crashes due to human behavior was led by an increase in the rate of distracted driving.
Rate of increase, 2014 - 2015
10%
8%
6%
4%
2%
0%
-2%
-4%
8.8%
4.9%
3.2%
3%
-3.2%
Distracted driving
Not wearing seatbelt
Alcohol
Speeding
Drowsy driving
Overall increase in fatalities
Reason for fatality
(Source: NHTSA)

Safety

Widespread use of autonomous vehicles could:

- eliminate 90% to 95% of all auto accidents in the United States,
- prevent up to US$190 billion in damages and health-costs annually and
- save thousands of lives.

McKinsey & Company

(Note: These figures are now widely disputed!)

Safety

Introducing autonomous vehicles ***sooner*** rather than ***later***, even before they are perfected, could save thousands of lives each year.

"Our work suggests that it is sensible to allow autonomous vehicles on America's roads when they are judged to be just moderately safer than having a person behind the wheel. Waiting longer will kill thousands of people unnecessarily." *

After each crash, the entire fleet would have its software adjusted, quickly perfecting the safety of autonomous vehicles. The complication is that crashes would continue to happen for a while before tapering off.

* - Nidhi Kalra, RAND Corporation, a California-based think-tank

Safety

Needless to say the idea that preventing 10,000 human error fatalities by having 7,500 computer error fatalities is somewhat controversial

Safety

Humans are the weakest link in semi-autonomous vehicles such as Tesla's Autopilot system.

"Maybe these intermediate levels [of automation] are not a viable consumer product. They go a little too far in encouraging drivers to check out and yet they aren't ready to take control." *

*** - Richard Wallace, the director of the Transportation Systems Analysis group within the Center for Automotive Research**

Safety

So some safety experts want to introduce autonomous cars ASAP to save lives.

And other safety experts want autonomous cars withheld until they are fully perfected with virtually no chance an autonomous car will make a mistake and kill someone.

The eventual solution is likely to be somewhere between these two extremes.

Safety

There has been considerable news coverage in May 2916 of the first Tesla accident where the driver was killed while driving using the Tesla Autopilot.

To put this in perspective, on the same day the usual 100 or so people in the US were killed in car accidents and hundreds more were injured, and nothing was said.

Safety

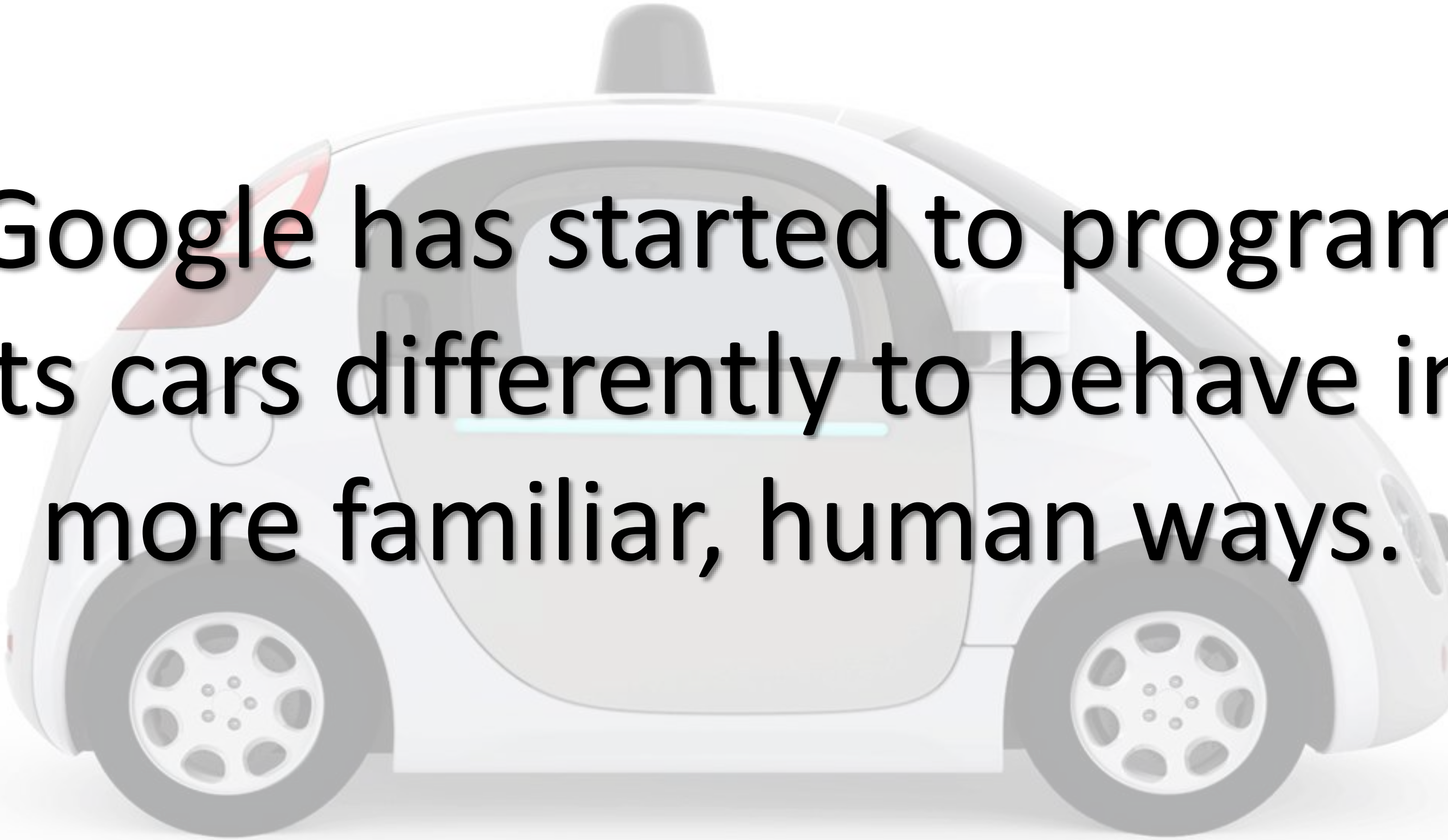
In real world testing the accident rates involving driverless cars are twice as high as for regular cars!!!


WHAT?

Safety

However the driverless cars weren't at fault - they are typically hit from behind by inattentive or aggressive humans unaccustomed to self-driving motorists being such sticklers for the road rules.

Safety



Google has started to program its cars differently to behave in more familiar, human ways.

Safety

No distracted drivers,

no road rage

Safety

No drunk or stoned drivers

Safety

Five years ago it was a given that autonomous vehicles would **GREATLY** improve road safety, but now there are several critics who make compelling arguments about why there may not be nearly as big an improvement as initially expected.

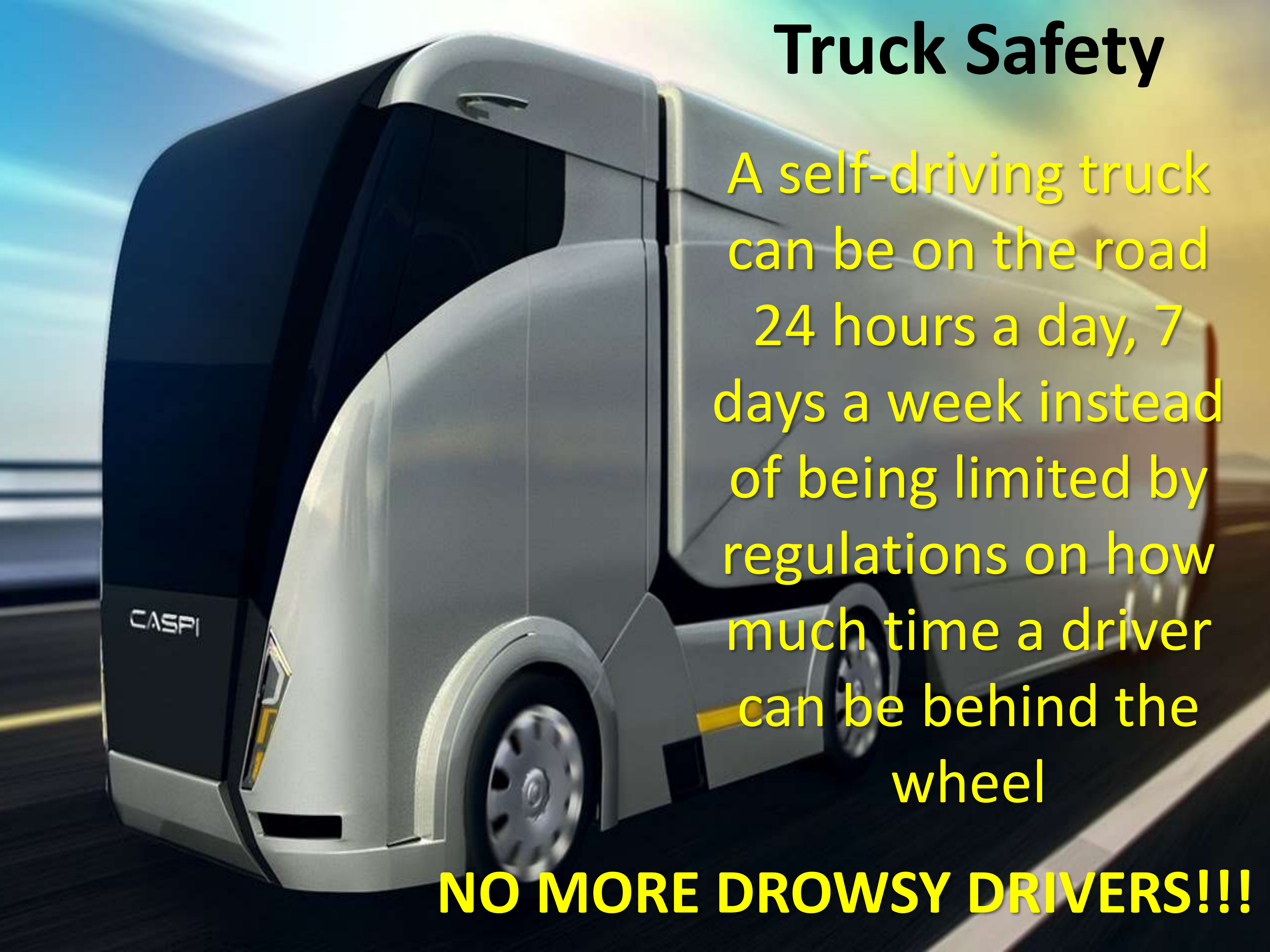
Safety

In reality, many of the safety benefits of autonomous cars might not be realized until almost all vehicles on the road are self-driven, not human driven.

Truck Safety

There have been several major accidents as a result of distracted, inattentive truck drivers piling into the back of stopped traffic.

Some of the results have been disastrous!


Truck Safety
A self-driving truck can be on the road 24 hours a day, 7 days a week instead of being limited by regulations on how much time a driver can be behind the wheel
NO MORE DROWSY DRIVERS!!!
CASPI

Safety

One of the advantages of autonomous vehicles is that, unlike some people, autonomous vehicles won't operate when conditions are more hazardous than they can handle.

But who decides what they can handle? The vehicle owner? The manufacturer? Public laws and regulations?

Truck Safety

You can watch *"Highway Thru Hell"* or *"Heavy Rescue 401"* on the Discovery Channel to see the consequences of driving big trucks in bad weather that the drivers can't handle

The Bad Weather Conundrum

Once ‘almost’ completely autonomous vehicles become ubiquitous, is it realistic to expect an inexperienced driver to take over in bad weather and difficult conditions?

Autonomous Car Benefits

The mobility of the young, the elderly, and the disabled will be increased.

Autonomous Car Benefits

Vehicle occupants could spend travel time engaged in other activities, so the costs of travel time and congestion are reduced.

- Texting
- Reading
- Napping
- Sex?

Autonomous Car Benefits

Fuel efficiency can be increased

Autonomous Car Benefits

Because such vehicles won't need nearby urban parking, downtown space used for parking could be repurposed.

Economic & Social Implications

Occupations based on driving such as:

- Truck driving
- Taxi and Uber
- Pizza and other deliveries

will become obsolete.

Issues on getting the goods from the vehicle into the building have yet to be fully worked out.

Amazon is experimenting with drones.

Economic & Social Implications

Other occupations and economies based on:

- public transit
- crash repair
- automobile insurance
- etc.

might suffer as the technology makes certain aspects of these occupations nearly obsolete.

Autonomous Vehicles will Affect Many Industries

Based on Accenture's global research, we have identified the seven sectors that will be most disrupted by the autonomous vehicle era.

Source: Accenture research

Economic & Social Implications

Prognosticators say other occupations such as artificial intelligence programming are expected to increase

This is likely to be short term until the systems learn to program themselves

Economic & Social Implications

Sociologists expect widespread use of autonomous vehicles will be a major contributor to the current increase in the *'Gig'* economy and the *'Minimum Wage/Part Time'* economy, and a big decrease in the Middle Class

Unknown Economic & Social Implications

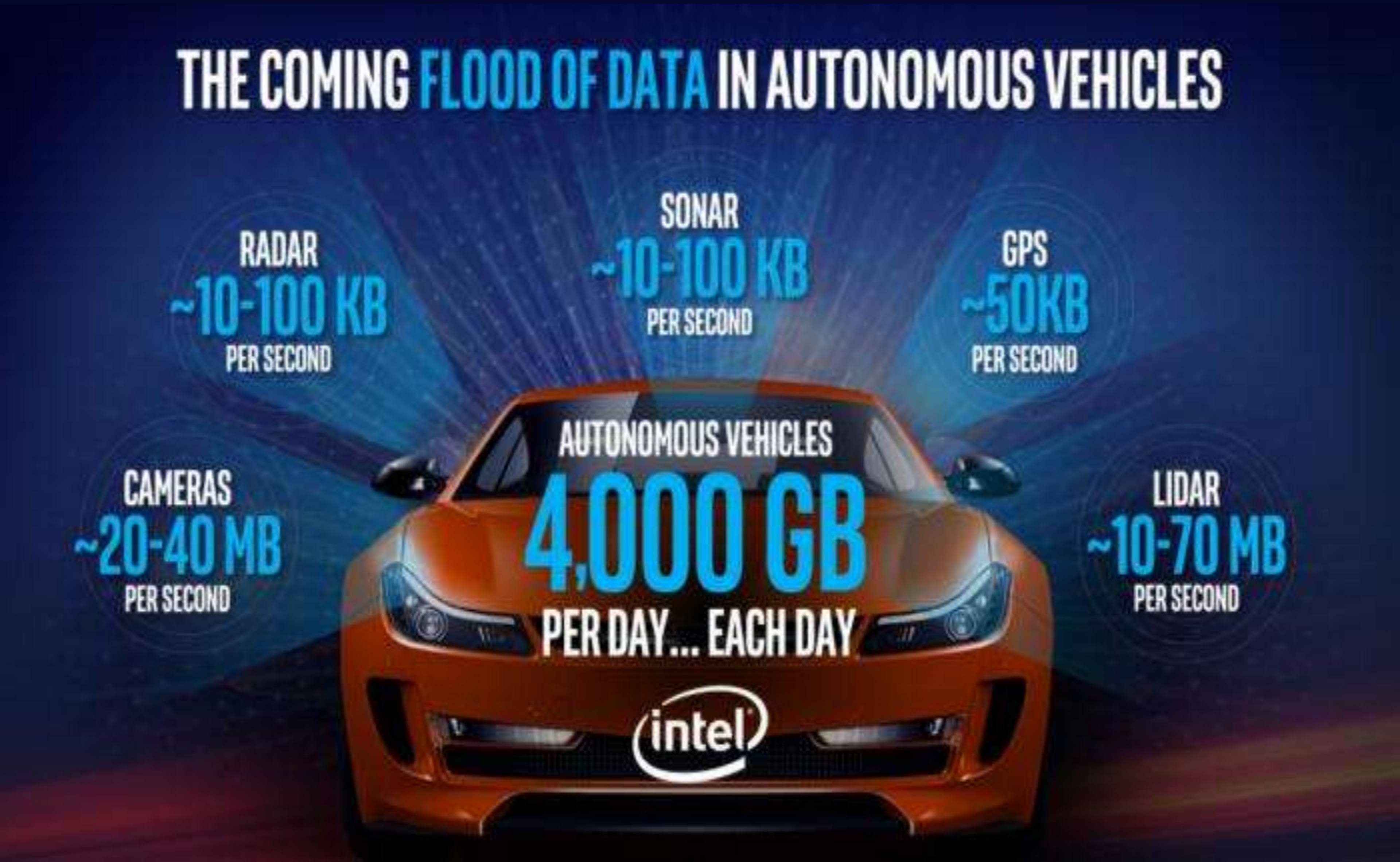
Utopia or Dystopia?

Some of the benefits of autonomous vehicles might be lessened by major economic displacement

Privacy Issues

Dubbed "***the new oil***", data is fast becoming one of the most valuable resources on Earth

BIG DATA – YOUR DATA



Privacy Issues

The interconnectivity of ~~autonomous~~ existing cars make them just another device that can gather information about you.

- where you go, how fast you drive
- voice recording,
- video recording,
- preferences in media,
- behavioral patterns,
- many more streams of information.

Privacy Issues

Right now in major accidents police confiscate the vehicle's computers to determine how fast the vehicle was going and other information pertinent to the investigation.

Privacy Issues

Google warned us a few years ago that your new smart TV may be listening.

Now your car might be listening too!

If You've Got a New Car, It's a Data Privacy Nightmare

What about hacking?

Cars ~~could~~ ***can*** be hijacked or stolen

Cars ~~could~~ ***can*** be crashed

Cars ~~could~~ ***can*** be held ransom
(vehicular ransomware)

What about terrorists?

Self-driving cars could potentially be loaded with explosives and used as rolling bombs.

Liability

Who should be held liable when an autonomous car causes an accident:

- **the car manufacturers?**
- **the software engineers that programmed the code?**
- **the car owner?**

Liability

Manufacturer liability is likely to increase while personal liability is likely to decrease.

If a vehicle and a human share driving responsibility, the insurance issues could become more complicated.

Policy Implications

Inconsistent national and provincial/state regulation poses a risk — if different jurisdictions have different regulations, it would be difficult for manufacturers to match them all.

Policy Implications

Vehicle owners might not be able to travel outside their jurisdictions of residence.

Various interjurisdictional agreements are expected to minimize this.

Autonomous Cars Usage in 2017

Many companies including Google, Tesla, Ford, Toyota, Honda, Nissan, Mercedes-Benz, Uber, Audi and others are testing self-driving cars (with safety drivers) on public roads.

Autonomous Cars Usage in 2017

Most Google StreetView cars are autonomous, although they have safety drivers

Autonomous Cars Usage in 2017

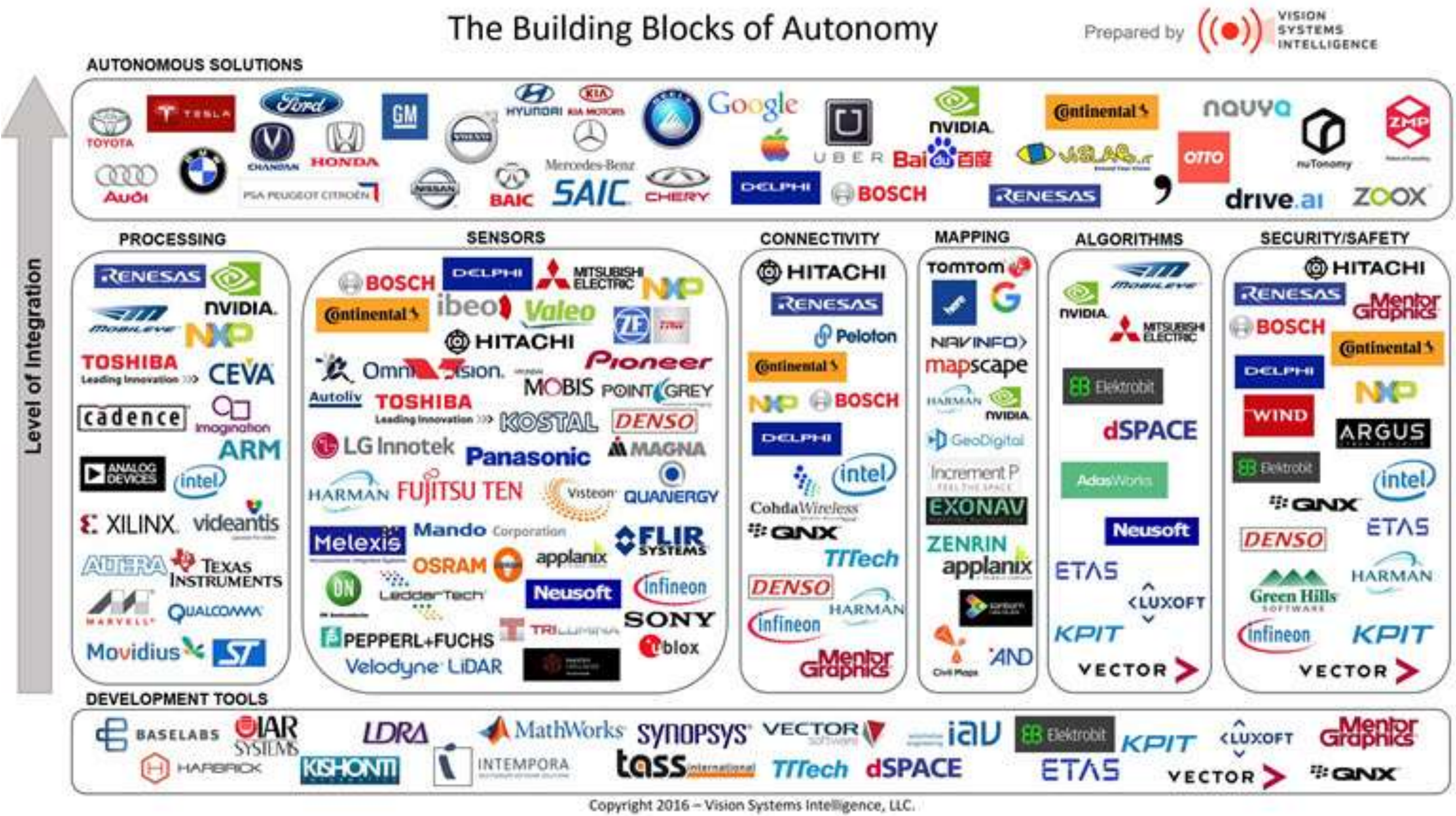
Uber has launched a self driven car cab service in partnership with Nutonomy in Singapore.

Autonomous Cars Usage in 2017

Autonomous cars ***without*** safety drivers are on the road ***right now*** in parts of Arizona and other places.

Autonomous trucks are expected on the road, at least on limited-access freeways between cities, within three to five years.

Some Companies Involved



Where is the city of Ottawa in all of this?

QNX

QNX makes Unix-like real-time fault-tolerant multitasking operating systems for embedded systems

QNX operating systems and other QNX software can already be found in more than 60 million cars around the world*.

QNX is based in Ottawa (Kanata)

*** - 2017 Data**

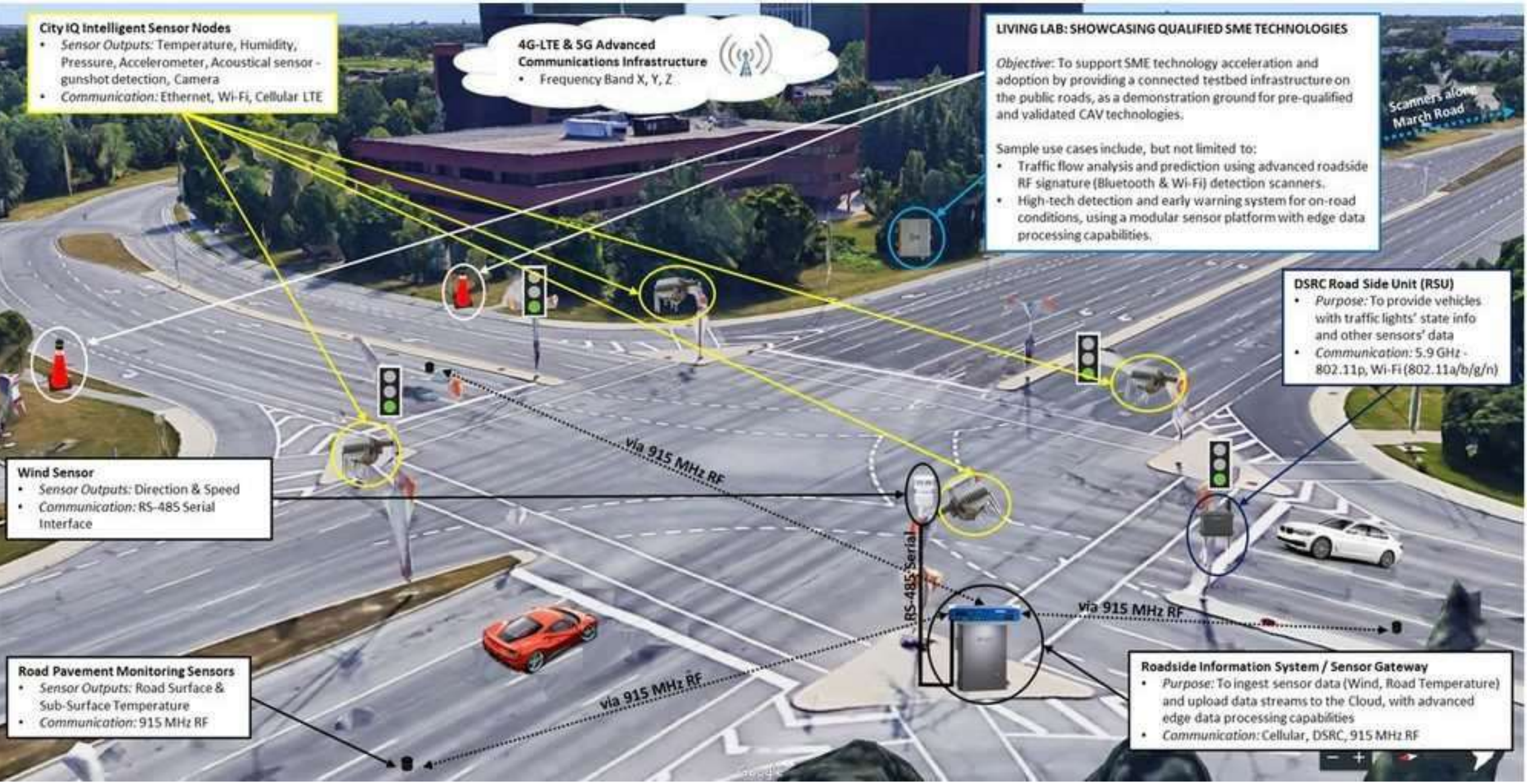
Edward Lee of QNX presented to OPCUG on 11 December 2013


Automotive Leadership
QNX
QNX SOFTWARE SYSTEMS
QNX is in 250+ vehicle models
QNX automotive
RENESAS
freescale
mobileGT
TEXAS INSTRUMENTS
Centrality
CSR
intel
AMD
FUJITSU
SPANSION
HARMAN/BECKER
JOHNSON CONTROLS
Continental
DELPHI
Visteon
Panasonic
LG Electronics
HYUNDAI AUTONET
DENSO
JVC
AISIN
DAEWOO
LEAR
Lectronix
Ford
Mercedes-Benz
Audi
HONDA
Jeep
ACURA
NISSAN
FLEETWOOD
GM
OnStar
CHRYSLER
SAMSUNG
KIA
MINI

2017 Data

Ottawa opened a 16-kilometre test track for cutting-edge autonomous vehicle technologies in 2017, the only such facility of its kind in North America at the time.

Test Track for Ottawa



There have been various Implementation Timelines proposed

AV deployment timeline

5-10 years	10-20 years	Beyond 20 years
▸ Controlled, AV-only environments ▸ Moderate level of automated driving ▸ Low to medium speeds	▸ Less restricted environments ▸ High level of automated driving ▸ Medium to high speeds	▸ Large, connected AV networks, allowing multiple mobility scenarios ▸ On demand mobility and fleet services ▸ Customizable AVs

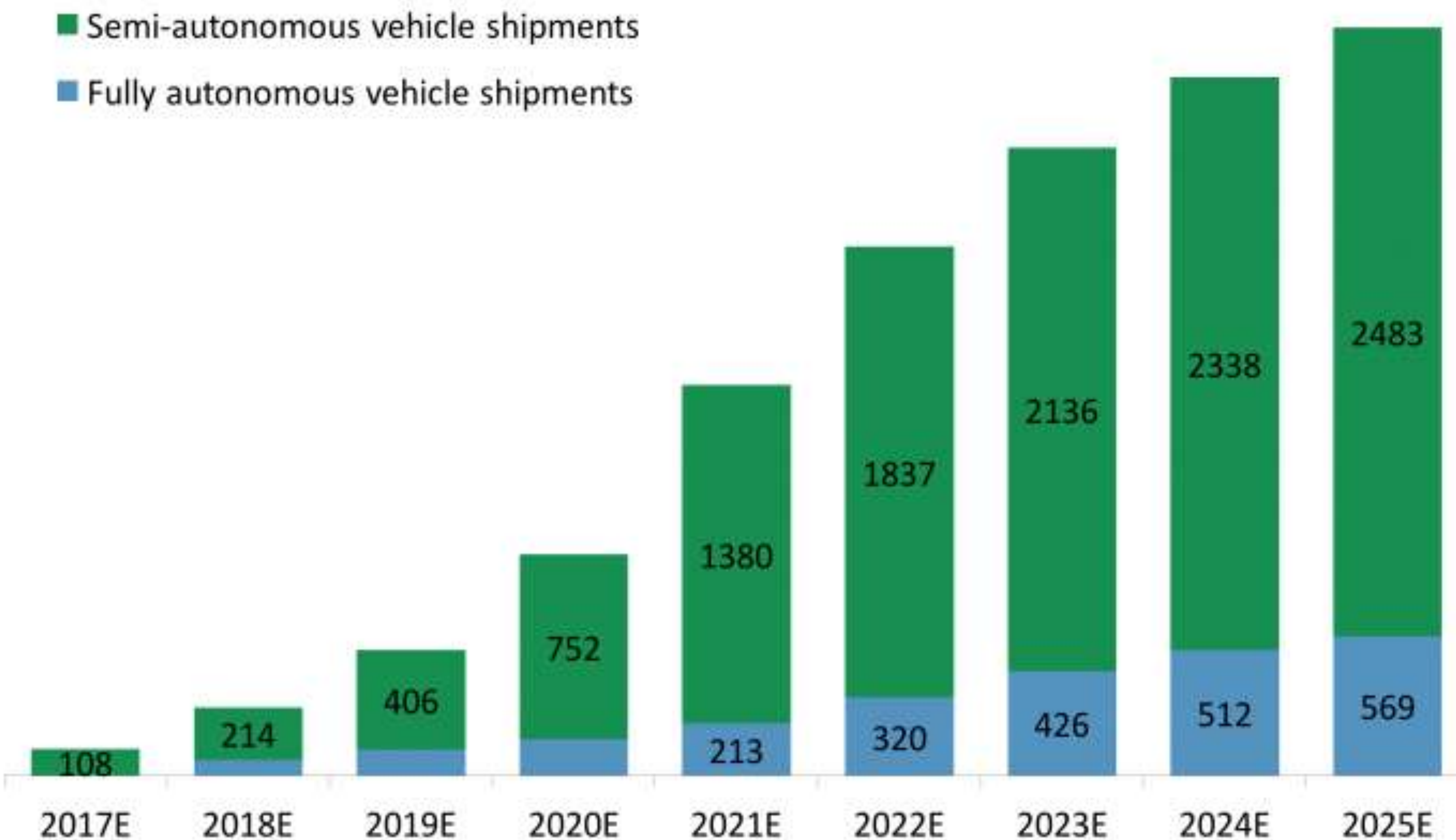
The Road to AVs in the Region

A Prospective Timeline in Four Phases

1. *2017-2022*
   Automated features continue to improve and become less expensive, while car ownership declines.
2. *2022-2027*
   Fully autonomous vehicles are on the market, but AV and legacy vehicle mix results in uneven traffic improvements.
3. *2027-2040*
   Autonomous conversion of light-duty vehicle fleets increases from 15 percent in 2030 to 75 percent in 2040.[1]
4. *2040 and beyond*
   Land use planning is permanently altered to make way for pedestrians, cyclists, and public spaces, in both urban and suburban streets.

FORECAST: Semi/Fully Autonomous Car Shipments

US, 2017-2025, Thousands



BI INTELLIGENCE

Source: BI Intelligence Estimates, 2017

Implementation

Once autonomous vehicles reach a critical mass, non-autonomous vehicles will likely be increasingly restricted or banned from certain areas

In remote and isolated areas human drivers will likely still be required for the foreseeable future

Who?

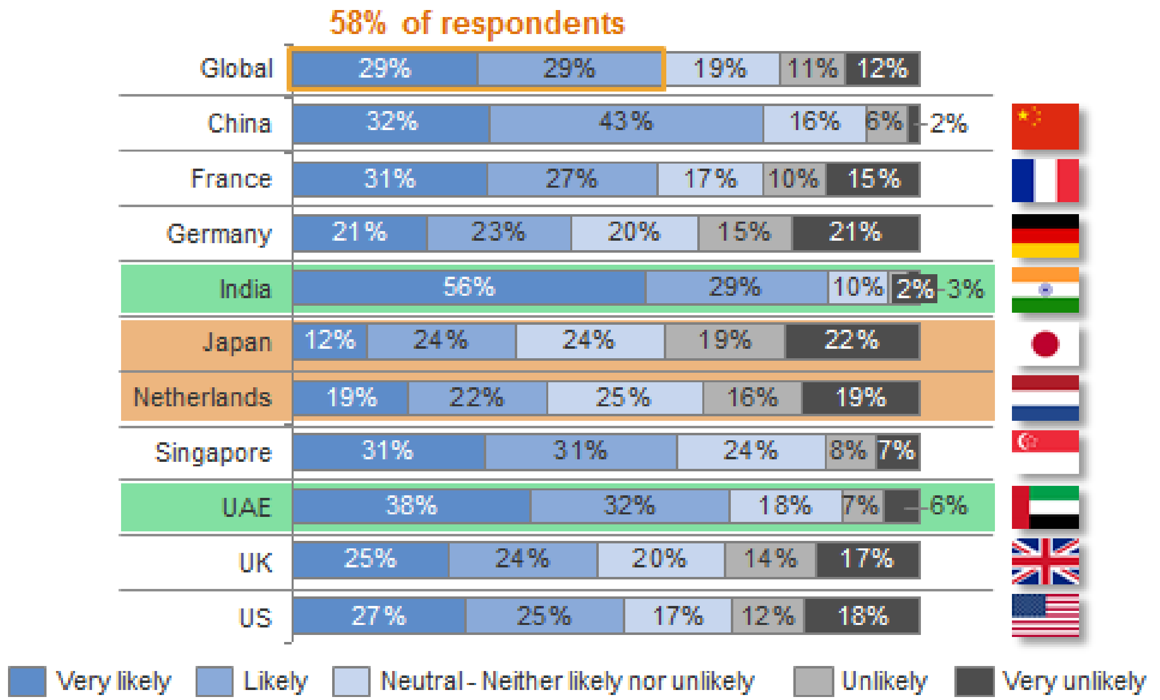
The biggest hurdle to the adoption of autonomous cars is not technical but human.

What if your autonomous car doesn't drive like you do? Say you're one of those people who drives *reallllly* slowly on the highway. How will you react when you're sitting in the front seat of a vehicle that drives faster than you're used to? Or vice versa. Will people be tempted to take control from these vehicles? Can we learn to trust them? If a vehicle requires you to suddenly take the wheel for some reason, will you be able to quickly turn your attention away from *whatever you were doing* while your car was doing the driving for you?

Many consumers are very open to trying a self-driving car

58% say they would take a ride in a fully self-driving car

In % of respondents per country



Q: Imagine that the **fully self-driving vehicle** became available in the market. How likely would you be to consider **taking a ride in it** (for example as a test drive, taxi or rental car)?

n=5,635

Note: This survey was prepared with the support of The Boston Consulting Group
Source: World Economic Forum; BCG analysis, consumer survey August 2015

Who?

Despite initial resistance by many people to autonomous cars, their introduction is expected to be similar to the smart phone. At first only techies and geeks bought smart phones and most other people thought they were a waste of money. Now, only a few years later, almost everyone has a smart phone.

Who?

Self-driving trucks and delivery vehicles will likely be the first autonomous vehicles on the road in any numbers as the employers opt to save money and get rid of personnel issues

Who?

In surveys, acceptance of self-driving technology was greatest with younger respondents, and those with higher incomes and education levels

Other early adopters will likely include those who otherwise have driving limitations such as the disabled and seniors

Who?

Millennials are expected to be early adopters

Seniors that still have a drivers license are expected to be resistant to self-driving cars

Older Drivers Resist Autonomous Vehicles and Ridesharing Services

Drivers 65+ find ridesharing services and autonomous vehicles unappealing but embrace auto technology when it comes to safe driving.

53% are not interested in **ridesharing services** because they prefer driving themselves

49% would be uncomforatable riding in a **fully autonomous vehicle**

57% own a car **without safety technology** features

51% of drivers are **willing to pay more** for blind spot detectors, back up cameras (43%) and automated braking (31%)

63% will **shop for their next car** with active safety technologies

Survey included 1,000 US respondents age 65 or older conducted by Munich Reinsurance America, Inc. 2-2017

Munich RE

Who?

"It's the middle-aged people … the people for whom getting a driver's license and getting a vehicle as soon as they could was part of the culture. It'll be a lot more difficult to get them to let go of the steering wheel. But even those people hate the drive to and from work and will eventually be won over by the advantages of autonomous vehicles.” *

* - Barrie Kirk, engineer and executive director of the Canadian Automated Vehicles Centre of Excellence in Kanata.

Who?

Curiously, surveys show that confident, capable drivers are more likely to use a self driving car than nervous, poor drivers

Who?

High risk drivers, including those who habitually drive while:

- Impaired and/or stoned
- Distracted
- Drowsy

will be among the early adopters to either avoid penalties or to get around suspended licenses.

Who?

13 per cent of those surveyed said they would turn off all automated systems so they could run red lights and speed excessively when they were running late for an appointment.


Driving for the
pleasure of driving
may become a thing
of the past

And what about motorcycles?

Already six times more dangerous than cars!

Autonomous motorcycles?


What about the freedom of the open road?

BUT…

When I did the first version of this presentation in 2017, companies including Tesla and Ford were predicting self-driving cars would be readily available by 2022.

However, while companies have been able to develop systems that can handle normal daily driving under normal conditions, they have found that making systems that can handle the endless 'edge' cases such as unpredictable drivers, road obstacles, poor/missing traffic controls, flawed maps, bad weather, following the instructions of a police officer managing traffic at a crash site, etc., etc., etc., is not that easy.

Most companies including Ford and Volkswagen that were very optimistic in 2017 have greatly scaled back and delayed plans for fully self-driving cars in favour of improving and expanding their semi-autonomous technologies.

Many companies are limiting the capabilities of their vehicles for legal and liability reasons.

Cars that can self-drive in cities with controlled intersections, pedestrians, etc. where the driver can take over for unusual conditions like road construction, accidents, emergency vehicles, rush hour traffic, traffic cops directing traffic, aggressive drivers, etc. are probably only three to five years away from a technical standpoint, but may be delayed by legal and liability issues.

It may be several more years after that before cars can reliably self-drive under ALL conditions including bad weather, and may still be limited in unusual situations like the remote winding cow path road into the cottage.

Since 2020, Waymo, Cruise (GM), Nuro and other companies have operated driverless taxis in US cities like San Francisco and Phoenix. Although there have been problems like unplanned and unexpected stops in travel lanes, where they obstruct traffic, transit service and emergency vehicles, their use is being expanded.

Other countries including Singapore and China also have driverless taxis in some cities.

Nuro began autonomous commercial delivery operations in California in 2021.

Vehicles like driverless taxis and delivery vans are able to operate now in some places because they are limited to very specific geographic areas, specific modes of operation and specific legal operating conditions.

Vehicles available to the general public can't be subject to such restrictions.

Self-driving tractors now plow many of our fields, some on optimal paths mapped by drones loaded with sensors*.

* - On 13 April 2016, Will Wegenast (Airborne Media Pros, Skyborne Systems) & Regie Alam (ASG Mappng Ltd.) gave a presentation "*A Discussion on UAVs: Exploring Emergent Unmanned Vehicle Technologies & Real-World Applications*" on this.


The future will probably be
messy, just like the past!!!

Some Other Autonomous Vehicles

- Ships
- Trains
- Drones
- Warehouse and factory equipment
- Underwater exploratory vehicles
- Paraplanes and gyrocopters (Ottawa company MMIST*)
- Mars rovers

* - Mist Mobility Integrated Systems Technology


THE END

Moral Responsibility

The question arises how autonomous vehicles should be programmed to behave in an emergency situation where either passengers or other traffic participants are endangered.

Moral Responsibility

Does a self-driving car veer off the road to save four pedestrians that walked out in front of it but risk killing its driver?

If a big truck veers in front of it, does the car hit it head on and kill four people in the car or does it veer onto the sidewalk and kill a woman with a baby stroller?

Moral Responsibility

There are two main considerations that need to be addressed:

- **First, what moral basis would be used by an autonomous vehicle to make decisions?**
- **Second, how could those be translated into software code?**

Moral Responsibility

Some suggest the idea that any decision must be made based on maximizing the number of people surviving in a crash.

Moral Responsibility

Others suggest that autonomous vehicles should adapt a mix of multiple theories to be able to respond morally right in the instance of a crash.

Moral Responsibility

But who decides?

Politicians?

Lawyers & Judges?

Car Companies?

The Owner?

Moral Responsibility

In a Toyota Canada-sponsored study at least two-thirds of the 2,662 Canadians who took the survey said that they wanted their self-driving vehicle to ***"prioritize the safety of vehicle occupants over other road users.***"

In other words, *“kill the other guy first”*.

Moral Responsibility

Many carmakers admit that the last long-term roadblock to a completely self-driving future are various ethical questions.

“Who dies when” and ***“Who gets to choose”*** are questions so uncomfortable that few carmakers are willing to discuss it in anything but the vaguest terms as they work on the design of these systems.

Moral Responsibility

These issues likely won't be finally settled until long after autonomous vehicles rule the road.

It will likely be up to the Supreme Courts of the various countries to finally decide.

Moral Responsibility

In reality, it is very seldom a human driver has to make such a decision, and we will be well down the road to a self-driving car future before the technology exists for the car to make such a decision.

Speed Variance

- The difference in speed between the slower vehicles on the road and the faster vehicles is known as “speed variance”.
- Wide speed variances are more dangerous than actual speeding as faster vehicles take risks to overtake and pass slower vehicles
- Platooning can enforce ‘speed harmonization’, allowing safer high speeds

Speed Variance

Roads have a 'natural' speed. Under normal traffic conditions in clear weather, 70% to 80% of the traffic will drive the natural speed of the road regardless of speed limits

EXCEPT

Some drivers who would otherwise flow with surrounding traffic will ***NOT*** exceed the speed limit even if it is too low.

Speed Variance

Even without autonomous vehicles, in many places speed variance can be reduced and the road made ***20% to 50% SAFER*** by ***RAISING*** the speed limit.

Speed Variance

In reaction to the energy crisis of 1973, in the US a national maximum speed limit of 55 mph (about 90 km/h) was imposed, and in Canada expressway and highway speed limits were dropped by 20 km/h in order to reduce gas usage.

Speed Variance

Safety experts claimed the reduction in accidents and fatalities proved that “speed kills”.

In reality, the reduction in accidents and fatalities was the result of people not driving nearly as much because of gas shortages and high prices.

Speed Variance

Once the energy crisis was over, accidents and fatalities rose to ABOVE pre-crisis levels as most drivers ignored the lower speed limits but some drivers stubbornly refused to exceed those limits.

In the 1990's thru the 2010's as speed limits in the US were raised, speed variance was reduced and accidents and fatalities on the affected roads were reduced by 20% to 50%.

Speed Variance

In Canada we've kept the lower speed limits and continue to accept the increased accidents and fatalities caused by speed variance because safety zealots and environmentalists are opposed to raising the limits and saving lives.

Starting in 2022, GPS-based speed limiters are mandatory on all new cars in the European Union.

The systems will limit the vehicle's speed to whatever the speed limit is.

Vehicles will be able to exceed the speed limit for short periods (e.g. to pass another vehicle), but the longer the vehicle is over the limit the more alarms and warnings will come on.

In-Car Experiences

Several companies are developing in-car advertising systems aimed mainly at ride-sharing, e-hailing and car-sharing vehicles.

Intel announced a collaboration with Warner Bros. to develop *“in-cabin, immersive experiences”*.

In-Car Experiences

General Motors ***was*** rolling out its Marketplace app which ***"… allows drivers to browse deals and place orders through an in-dash touchscreen with several major brands such as Starbucks, TGI Friday's, Priceline.com and Dunkin' Donuts".***

GM expressly said Marketplace is intended for use ***while driving***.

Is the idea of somebody browsing deals and placing orders while they drive a good idea?

GM was weaseling around distracted driving laws because the laws generally target handheld devices, not hands-fee devices built into the cars.

Your Car As Your Friend

Thirty-five years ago the TV series *Knight Rider* envisioned an artificially intelligent car that developed a friendly rapport with its driver. That 1982 Pontiac Trans Am dutifully served as Michael Knight's crime-fighting partner, monitored his health through sensors in the seat and even used voice analysis to respond to the sarcasm in Knight's quips.

Your Car As Your Friend

- Honda, Toyota, Mercedes and several other companies are planning to make AI infotainment standard in all the vehicles they produce.
- The systems would analyze and respond to data the vehicle collects about driver and passenger preferences and behavior.
- They would be an automotive version of Amazon Alexa, Apple Siri, Microsoft Cortana, Google Assistant and IBM Watson but on steroids.

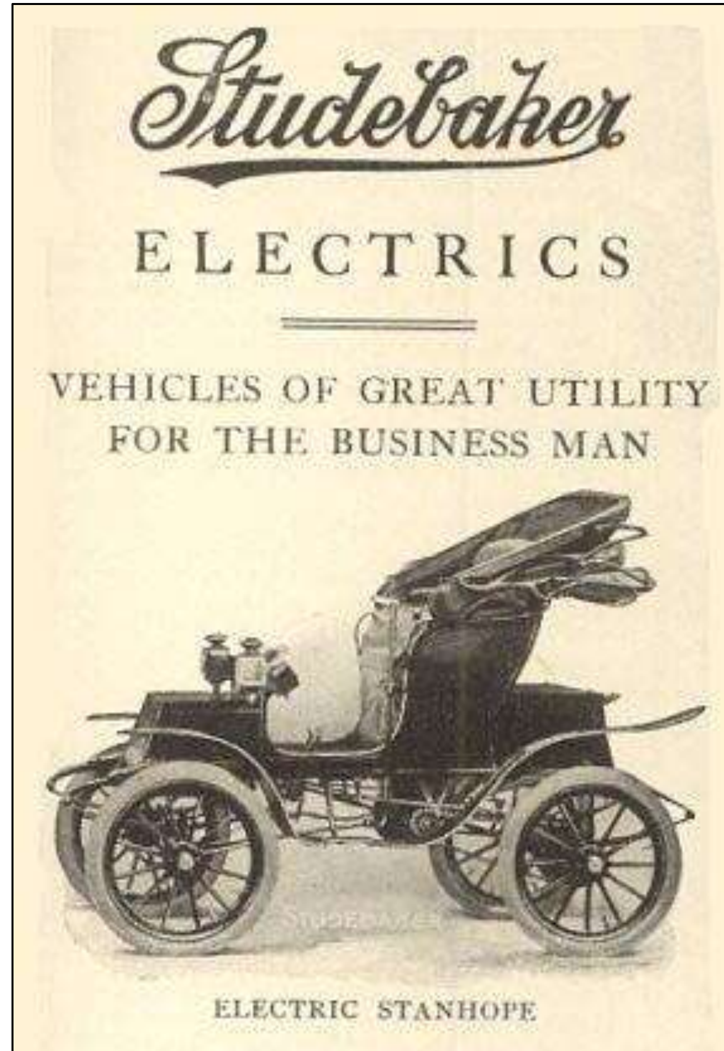
See the section on 'Privacy' for the implications of this!

A Few Words On Electric Cars

Electric cars and autonomous cars are often mentioned together

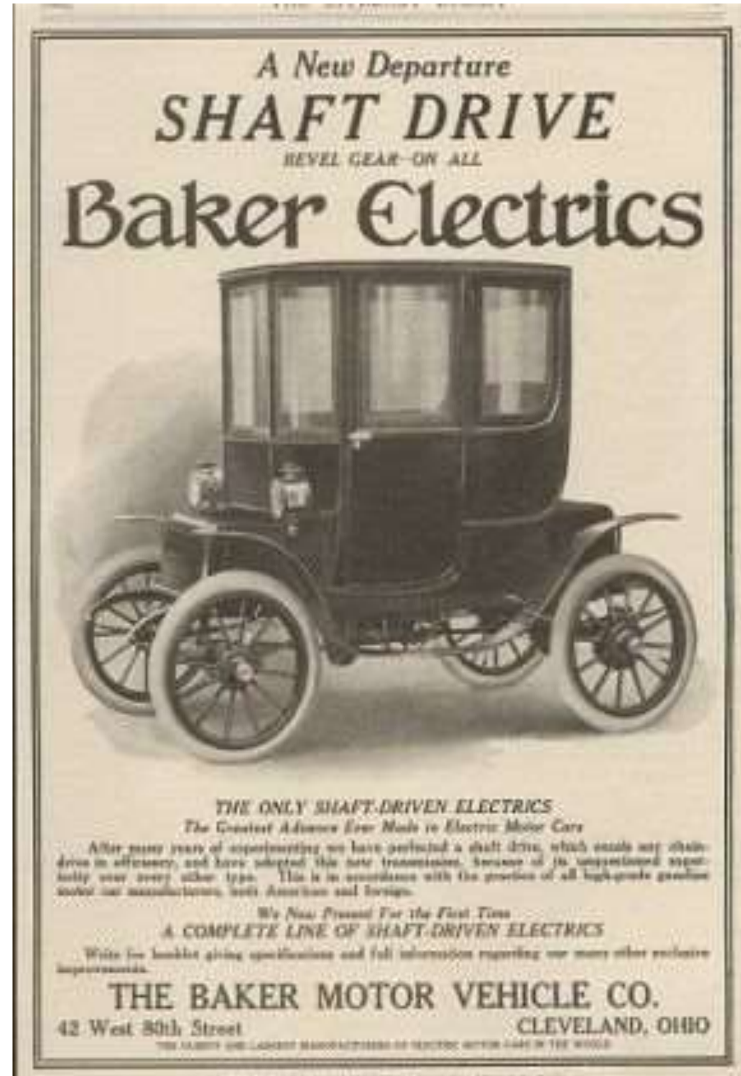
Electric Cars

Electric cars have been around for a long time, and were quite popular in the early 1900’s



Electric Cars

They suffered from the same two issues as current electric cars – range and charging times



Electric Cars

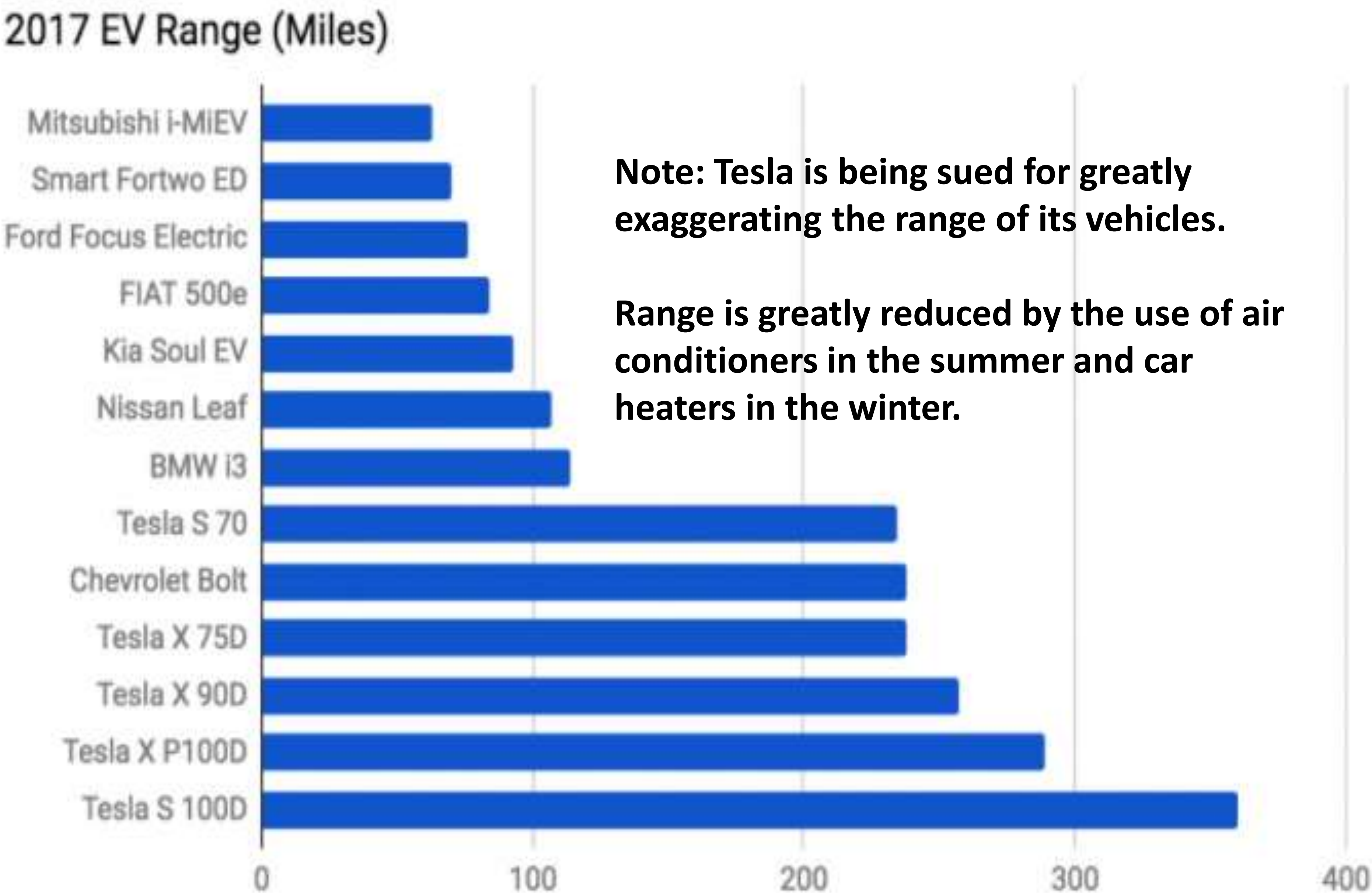
Electric cars are emissions free

Several governments are promoting them with subsidies and other incentives

France and England have banned internal combustion engines starting in 2040, several other countries are considering doing the same.

Electric Cars

Because of their limited range and the current lack of fast charging stations, drivers of electric cars tend to suffer from “range anxiety”.



Note: Tesla is being sued for greatly exaggerating the range of its vehicles.

Range is greatly reduced by the use of air conditioners in the summer and car heaters in the winter.

The vehicle cost divided by the range in miles is usually $350 to $400 per mile of range

Electric Cars

People want to charge their electric cars *AT NIGHT* so that the next day they can go to work, go shopping, take the kids to hockey and soccer and otherwise go places where they *CAN'T* plug the cars in, so solar power can't be used for charging

Electric Cars

People also want to charge their electric cars *AT NIGHT* to take advantage of ‘time of use’ electrical rates used in many jurisdictions.

Charge your electric car in 15 minutes

EPFL researchers propose to store energy from the power grid in a buffer to allow ultrafast charging of hundreds of electric cars with grid overload protection.

Gasoline and diesel

96% of today's cars. Rapid refueling and long range, but harmful for the environment.

Electricity, home charging

Most common charging method for today's electric cars. Growing risk of overloading the electric grid due to increasing popularity and power requirements.

Electricity, ultrafast charging

Buffering allows for rapid charging of hundreds of cars without overloading the electric grid.

A highway rest stop (e.g. Highway 401) will require 200 fast charge stations and a 20 megawatt electrical supply to have the same throughput as 20 gasoline pumps.

Range issues with electric cars may require up to 300% more rest stops.

Electric Cars

There is a suggestion that electric cars could be charged during the day using solar power and act as a 'battery' to power the electrical grid at night, but when would you get to drive them?

There would need to be a very comprehensive charging/discharging infrastructure in place to enable this.

Electric Cars

There would need to be charging stations in most parking lots, including at work, shopping centres, arenas, restaurants, etc.

There would need to be massive upgrades to the electrical grid to handle the extra power required.

Who is going to pay for this?

Electric Cars

Recent agreements between car manufacturers indicate that the Tesla SuperCharger network may become the defacto standard for charging electric cars, at least in North America.

Electric Cars

The batteries on most electric cars will discharge on their own over a period of a few weeks, so cars left idle for extended periods need to be ‘topped up’.

Electric Cars

Electric utility companies have no idea yet how electric cars will affect electricity demand in the future

Electric Cars

Dealers don’t like electric cars because of low maintenance requirements

Car companies lose money on electric cars

Electric Cars

Producing the batteries for one electric car releases the same greenhouse gases as 4 to 8 years of gasoline driving!!!

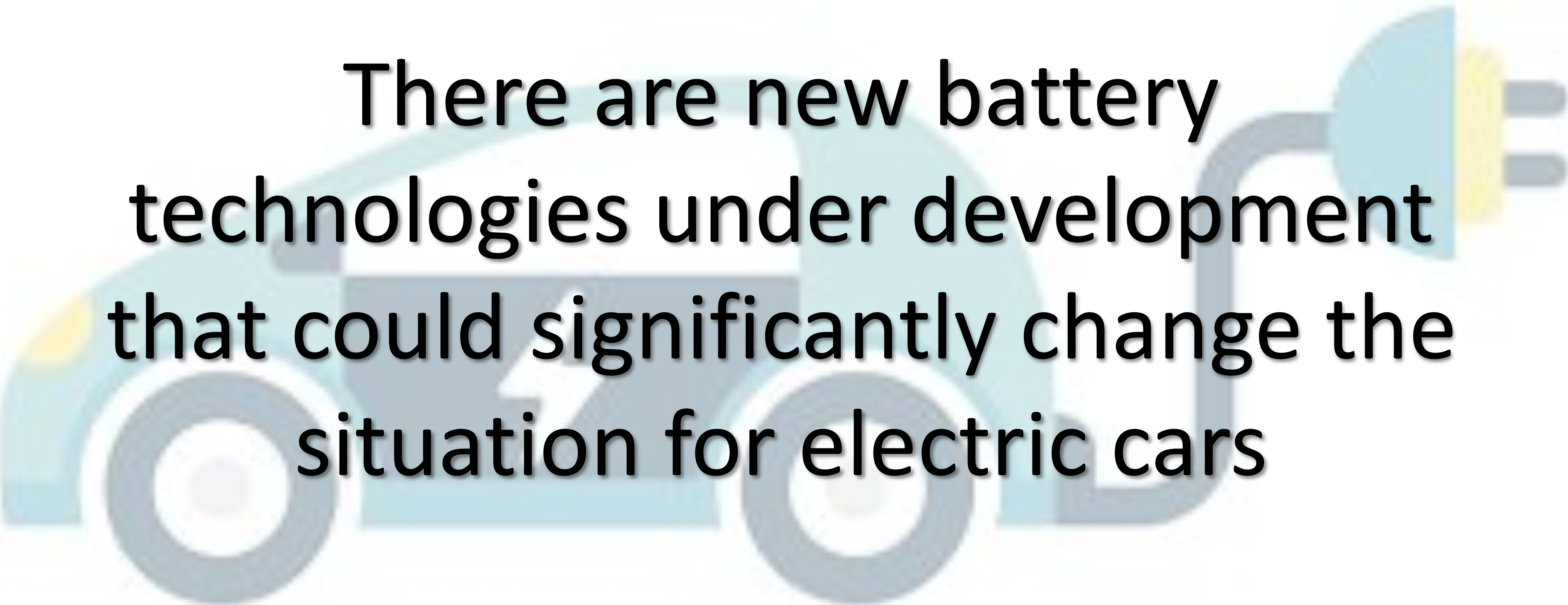
Electric Cars

Lithium-ion battery fires can be spectacular, and are incredibly difficult to put out.

Electric Cars

Electric cars are not emissions free if they are charged with electricity generated by coal, natural gas, etc.!!!

Electric Cars



There are new battery technologies under development that could significantly change the situation for electric cars

Plug-In Hybrids

Two types of Plug-In Hybrids

(1) Those that are basically the same as regular hybrids that usually run off of the gasoline engine with the electric motors as ‘helpers’, but can also be plugged in to charge the batteries.

These are not as energy efficient and as environmentally friendly as the second type.

Plug-In Hybrids

Two types of Plug-In Hybrids

(2) Those that always run off of the electric motor(s), while the gasoline engine works only when required to charge the batteries.

The gas motor is just a generator and can be optimized to run at a constant speed, and is thus more efficient and the less polluting.

The gas motor is mostly used to extend the range when plug-in charging is unavailable.

Plug-In Hybrids

EVs with on-board gas generators (as opposed to hybrid vehicles) are an immediate and real-world solution to emissions while the many issues with fully electric cars are worked out.

- They reduce emissions by at least 75%
- They use the existing gasoline distribution systems while the charging station issues are being worked out
- Can also be plugged in to charge the batteries, further reducing emissions
- No range issues

Tesla Unveils Electric Big Rig

- Will be capable of travelling 500 miles on a charge with a 80,000-pound load
- The truck will have an advanced version of Tesla's Autopilot system, which can maintain a set speed and slow down automatically in traffic.
- Several Tesla semis will be able to travel in a convoy or platoon, autonomously following each other.

Tesla Unveils Electric Big Rig

Several high profile companies have pre-ordered fleets of Tesla trucks for public relations reasons, even though they won't start production until 20?? at the very earliest. The list includes Pepsi, Walmart and Anheuser-Busch.

Tesla Unveils Electric Big Rig*

The Anheuser-Busch Clydesdales are reportedly very happy with this. They are tired of breathing in the diesel fumes from their existing truck.

* - Production began in October 2022, and initial deliveries were made to PepsiCo on December 1, 2022.

About the Presenter

Prior to retiring a few years ago, Bob was a Senior IT Project Manager with the Public Health Agency of Canada/Health Canada for 14 years. Before that he worked for several companies in the Hi-Tech private sector for over 25 years, including positions as Quality Assurance Manager, Production Manager, Industrial Engineering Specialist and Production Planner & Controller.

Bob has been a member of the Ottawa PC Users Group (OPCUG) (opcug.ca/public/index.htm) for about 30 years and currently serves as their Facilities Coordinator. He frequently makes presentations on various computer related and other topics such as Relational Databases, Business Intelligence, Accessible Computing, Web 3.0, the History of Computing, Self-Driving Cars and Renewable Energy. Along with the rest of the OPCUG Board, he received an Ontario Volunteer Service Award for his work with OPCUG.

Bob currently serves as Chair and webmaster for the Burritt's Rapids Renewable Energy Association (www.brpower.ca), a not-for-profit community organization. BRREA's focus is on the development of a small hydro project, generating energy from the Rideau River water flow at the existing dam site upstream from the village, and using all income (after covering costs) to fund community projects and initiatives.

Bob was involved in skydiving for over 30 years, making 1,400 jumps (including 3 BASE jumps) and accumulating 14 hours of freefall time. He holds a Senior Instructors License, an Exhibition Jump License and a Parachute Rigging Technetium Rating from the Canadian Sport Parachuting Association (CSPA). He also has an Advanced Scuba Diver certification from the National Association of Underwater Instructors (NAUI) and was married to his wife Cindy underwater near Key Largo, Florida.