

March 2016

CDR



# Autonomous Car Design Contexts By Car Design Research for GATEway Driverless Car Project

# Autonomous Car Design Contexts



## Contents

- › Project brief and background
- › Historical context of autonomy in transport
- › Key autonomous car developments
- › Technical parameters
- › Socio-cultural consumption of autonomous travel
- › Potential next steps: research opportunities
- › Car Design Research Overview

# Autonomous Car Design Contexts



## Project brief and background

- › This project is a result of a verbal briefing from Professor Dale Harrow, Dean of School for Design at the Royal College of Art to Sam Livingstone, Director of Car Design Research in early March 2016.
- › The brief was to create a useful summary of all key contexts that sit around the emergent field of autonomous cars as a basis to inform a wide range of people involved in research in this area. Specifically, the material needed to be presented clearly and succinctly with extensive use of imagery – potentially to directly inform a related exhibition.
- › This project has been completed by Car Design Research – a UK based automotive design strategy agency with extensive experience working for automotive OEM Design groups in many areas including autonomous cars.

# Historical context of autonomy in transport



# Historical context of autonomy in transport



Flying carpets were the first vision of an 'autonomous vehicle'

- › By 130 BC, a magic carpet supposedly flew King Phraates II of Parthia to battle. Flying carpets have graced folktales from Russia to Iraq. Picture below: "Flying Carpet", by Viktor M. Vasnetsov, 1880.
- › They combine two once-fantastic dreams: autonomous vehicles, and flight. (Credit: Wikimedia Commons) – and are perhaps known by everyone; the near-ubiquitous socio-cultural context for autonomous travel



# Historical context of autonomy in transport

## Horse drawn (delivery) road vehicles

- › Prior to the advent of the (motor) car, the horse drawn carriage and cart had many autonomous qualities – a horse has sufficient intelligence to adjust its speed and direction of travel in a variety of circumstances
- › In particular a horse drawn delivery cart - classically the milk float - would often move along the road from house to house without a driver.



The horse drawn delivery cart was common in the UK until the immediate post-war period, and is still a common sight in many other (developing) countries today



# Historical context of autonomy in transport



Lifts (elevators) were the first real autonomous vehicles people experienced

- › Since the late eighteenth century, manned (operator-elevators) and then later unmanned (autonomous), elevators / lifts have become the established means of travelling up a tall building
- › Critically, the lift has enabled the vision of the skyscraper to become reality and become the most accepted form of autonomous conveyance in the world.



Today lifts are uniquely ubiquitous as forms of autonomous transportation; universally accepted by the vast majority of people as a safe and convenient conveyance

Elevators also dictate much of the infrastructure they support; they form a straight, vertical route around which a tall building must be built; the nodes and system around this form or transport are subservient to it



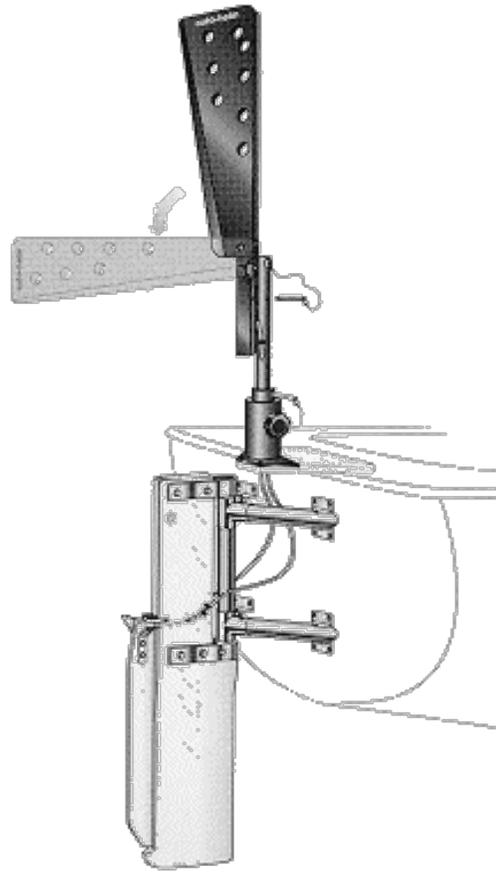
# Historical context of autonomy in transport

## Auto-helm

- › Self-steering, or auto-helm, was first used by ships in the nineteenth century, and then from the nineteen-thirties by larger yachts looking to travel long distances or race.
- › Some sailing craft use a wind-vane system that keeps a constant trajectory relative to the direction of wind. Other vessels use electronic systems that follow a pre-set route – some with intelligence to alter this en-route

The wind-vane auto-helm system used in some sailing boats affects the course of the craft depending on its angle relative to the direction of the wind.

This is ideal when trying to sail as 'close to the wind' as possible and or when not having to frequently adjust the cut of the sails is ideal - typically over a long distance.



# Historical context of autonomy in transport



## Self-guided torpedoes and guided missiles

- › The first missiles and under-water torpedoes in the early part of the twentieth century lacked any guidance system, but by the end of the second-world-war they used acoustics to home-in on targets.
- › These autonomously directed machines are distinct in that they need to follow no or little set path or system between their start point and target as they move through water and air with no obstacles.



The German V2 rockets, of the latter part of the end of the second world war, used 2 mechanical gyroscopes (horizontal and vertical), an accelerometer and a mechanical computer to keep them on target. The last few V2s used 'guide beam' radio signals transmitted from the ground.

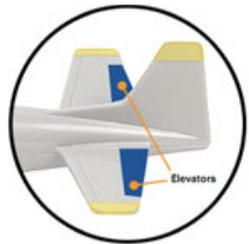
Modern guided missiles and torpedoes use some form of radiation from the target (infrared, radar, radio waves, heat). Or use a geo-specific guidance system (where the target location is known). Or a combination of both – where the geo-specific guidance system is then taken over by a target fix.



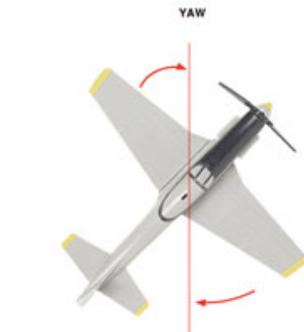
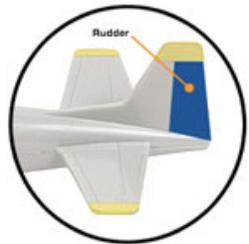
# Historical context of autonomy in transport

## Autopilot – automatic flight control system (AFCS)

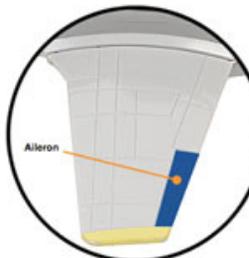
- The first autopilots were gyroscopic-based devices prototyped first in 1912 to enable a plane to hold course with no intervention from a pilot. This was first adopted for a passenger flight in 1931. The first fully autopilot flight, with take-off and landing, was a transatlantic flight in 1947 in a Douglas C-47 Skytrain
- Today international aviation regulation mandates some form of autopilot for all aircraft with 20 or more seats.



PITCH



YAW



ROLL

The three core control surfaces that autopilot may control – with some of the simpler systems in smaller craft affecting only roll or only roll and pitch.

The autopilot panel of a Boeing 737 – with the core mode engage switches and over-riding disengage switch circled. All modern airliners have autopilot that enables them to climb, cruise, descend, approach and land.



# Historical context of autonomy in transport



## Autonomous space vehicles

- The first un-manned Rovers were either remote controlled from nearby or from an earth based centre.
- For exploring celestial bodies / planets remote from earth, autonomous control is necessary – a signal takes 21 minutes to travel from Mars to earth negating the scope for real-time remote control.

The first un-manned (remote controlled) space Rover was Lunokhod 1, carried by the Russian spacecraft Luna 17 which operated on the moon from 17 November 1970 to 14 September 1971

In 2013 NASA's Mars rover 'Curiosity' pioneered with autonomous navigation (auto-nav) where it analysed images it takes in stereo of the path ahead to calculate a safe driving route.



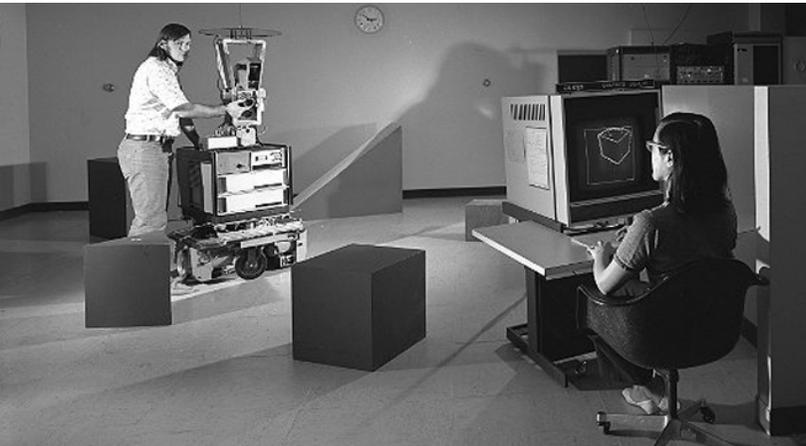
# Historical context of autonomy in transport

## Military autonomous vehicles

- Military Unmanned Ground Vehicles (UGVs) have been a significant player along the road to autonomy.
- These vehicles exist primarily to reduce the risk to military personal by replacing their function to drive vehicles and personally haul equipment. They vary from part or fully autonomous existing vehicle typologies to dedicated unmanned vehicles of many sizes including small Man-Portable Robotic Systems (MPRS)

'Shakey', the 1961 wheeled robot developed by the Defence Advanced Research Projects Agency (DARPA) - part of US Department of Defence - was the first of many subsequent autonomous projects

2011 Lockheed Martin 'Ox' (immediate right) is a dedicated unmanned vehicle that is part of a Squad Mission Support System (SMSS) that brings equipment to soldiers working on the front line. Others (such as the Israel Guardium - far right) can be manned or unmanned



Experimental legged 'mule-type' autonomous vehicles are in development for traversing particularly rough terrain (far right). Man-Portable (or Man Transportable) Robotic Systems (MPRS or MTRS) are already in operation but fast developing in ability



# Historical context of autonomy in transport



## Automatic Train Operation - Driverless trains

- › Automatic Train Operation (ATO) with progressively greater Grades of Automation (GoA) is progressively being rolled out across metro lines and general train networks internationally
- › Although they run on rails, or guided tracks, driverless trains such as the Docklands Light Railway (DLR) play an important role in conditioning the expectations of the general public to autonomous vehicles.



The London Underground Victoria line was the first train line with ATO in 1967.



1983 Gatwick 'People Mover' was the first UK GoA4 driverless train

1987 Docklands Light Railway was the first UK GoA3 level public train service



Automatic Train Operation (ATO) is the term for systems that may operate without train drivers. There are five Grades of Automation (GoA) for trains set out by the International Association of Public Transport:

- › GoA 0 is on-sight train operation: similar to a tram running in street traffic
- › GoA 1 is manual train operation: driver controls starting and stopping, operation of doors, handling of emergencies and diversions
- › GoA 2 is semi-automatic train operation (STO): automated stopping but a driver starts train, operates doors, drives train if needed - and handles emergencies. Many ATO systems are GoA 2 – such as much of London Underground.
- › GoA 3 is Driverless Train Operation (DTO): automated starting and stopping but train attendant operates doors and drives in emergencies
- › GoA 4 is Unattended Train Operation (UTO): starting and stopping, operation of doors and handling of emergencies are fully automated

# Historical context of autonomy in transport

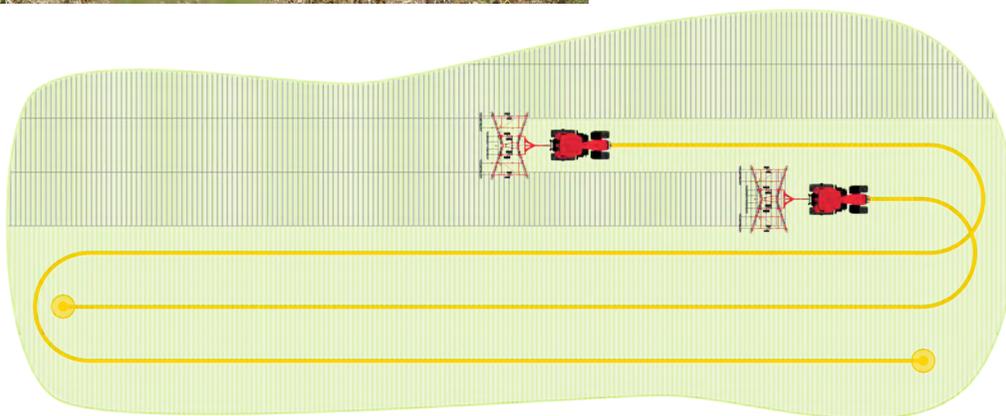
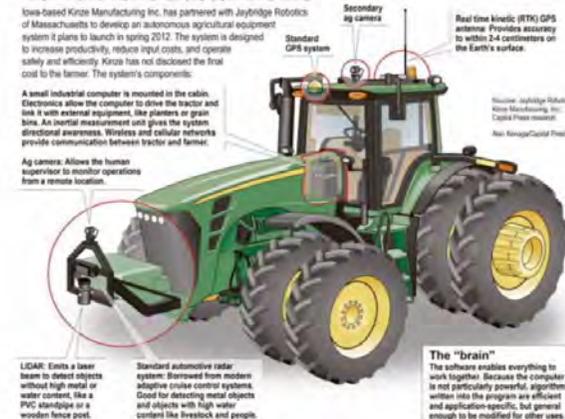
## Farm vehicles

- › Since 2003, partially autonomous farm vehicles — such as tractors and harvesters have been offered and are used increasingly within large scale agriculture operations
- › Automation is like to be one of the biggest impacts on farming in the future — with harvesting of crops becoming automated and automation/robotics vastly increasing efficiency and reducing wastage



Currently, autonomous farm equipment is often used alongside another (e.g. autonomous tractor/trailer, shadowing a combine harvester). This reduces the human cost factor for such activities by half

Modern autonomous tractors — such as this Kinze Manufacturing tractor from 2012 — have a surprisingly complete array of autonomous functions, such as LIDAR sensors. One challenge that remains for autonomous farm vehicles is the poor mapping of off-road areas and patchy GPS signal in remote areas



Potential future benefits of autonomising farming, include more precise ploughing/sewing but also harvesting (see cabbages, right) currently picked in a highly manual, labour-intensive way with a lot of wastage created



# Historical context of autonomy in transport

## Personal Rapid Transit - Podcars

- Personal Rapid Transit (PRT), or Podcars, are small pod-like vehicles that automatically travel on tracks from point to point. Conceived in the 1950s and extensively prototyped in the following decades, only a few have come to full maturity - there are now four operational PRTs globally, but this looks set to increase.
- Like driverless trains, PRTs play an important role in conditioning the expectations to autonomous vehicles.



The Morgantown (west Virginia) PRT is the world's oldest and has remained in continuous service since 1975. It operates 20 person cars on a 13.2km guide way.



2011 Heathrow Ultra Light Transit (ULtra) has 21 4-seat cars as a PRT system that runs 3.9km from terminal 5 to a car park.



PRTs are a direct consequence of the 1968 HUD reports (funded by the Urban Mass Transportation administration - UMTA - of the US Department of Housing and Urban Development - HUD) that cited the need and opportunity for Podcar type transit systems



# Key autonomous car developments

CDR



# Key autonomous car developments

The early days where road and car were both part of the system

- › In the pre-war years there were some experiments with remote radio controlled cars – but it was not until the 1958 RCA and GM collaborated that a truly autonomous, full size car first ran
- › These early concepts required a pairing of dedicated roads and cars – an ‘automatic highway’ to communicate with the autonomous car - not just the car itself working on existing infrastructure



First developed in 1953 in small scale, in 1958 (and then more fully realised with press taking rides in 1960), RCA Labs and GM realised a prototype autonomous car system with a series of detector circuits in the road surface that communicated with the car to direct its speed and direction.

As these pictures show – the ‘automatic highway’ was a major part of the concept.

This was expected to be realised commercially by 1975.

During the 1960s the UK Transport and Road Research laboratory tested a driverless Citroen DS (now in the Science Museum) on a dedicated stretch of the M1 (before it was opened to the public) that had two cables buried under its surface - one to control the speed and separation of cars (with road-trains to increase the road capacity behind this idea) the other to control steering.

A Cortina and a Mini were also converted.



# Key autonomous car developments



## The second stage, where cars navigated using cameras

- Previous autonomous systems required wires to be embedded in the road surface, but later experimental systems of the 1970s and 1980s had cars that 'read' (sometimes dedicated) road markings and other key environmental elements using cameras and (often physically huge) computers

The Stanford Cart was an electric buggy developed in the sixties and used throughout the seventies by Stanford University, US. In 1979 Hans Moravec developed it for his PHD with autonomous capabilities such that it crossed a chair filled room without human intervention in 5 hours. It paved the way for the Stanford autonomous Volkswagen Touareg (Stanley) developed in 2004

In 1977 S Tsugawa and his colleagues at Tsukuba University, Japan developed the first car to run driverless by tracking white street markers with machine vision only (using two cameras) – no dedicated road with embedded communications. The prototype ran at 20mph.

The 'vision guided' Mercedes VaMoRos van of 1986, developed by Ernst Dickmann Bundeswehr and the University in Munich, Germany pioneered technically with the use of Saccadic Vision, Kalman filters and Parallel computers. It initially attained 96kmh on 20km of traffic free streets. Version 2 (1991) developed it further. Version 3 (1997-2004) used commercially available parts and more powerful computing and cameras



# Key autonomous car developments



## Into the 1990s

- Still driven mostly by a macro infrastructure (governmental) lead approach / ambition of reducing traffic congestion and reducing road traffic accidents – the nineties saw a clear direction emerge that embraced multiple technologies and specifically a multi-camera based way of orientating the car in space
- In Europe the Prometheus programme much helped European organisations lead the field relative to the US

Prometheus (PROgramme for a European Traffic of Highest Density and Unprecedented Safety) ran from 1987 – 1995 with unprecedented funding of 749 million Euros from EUREKA (a European intergovernmental organisation for pan-European R&D funding and coordination).

The VaMoRos Mercedes van and S-class developed with Bundwehr University and Mercedes Benz were part of this programme, as was The Argo project run by the Universities of Parma and Pavia in Italy – and numerous other companies including Lucas and Jaguar in the UK (who together focused on areas including night vision and active cruise control with automatic braking, and lane departure warning)

The project culminated in a 'Board Members Meeting' on 18–20 October 1994 in Paris. Projects demonstrated ('Common European Demonstrators') were:

- CED 1 : Vision Enhancement
- CED 2-1 : Friction Monitoring and Vehicle Dynamics
- CED 2-2 : Lane Keeping Support
- CED 2-3 : Visibility Range Monitoring
- CED 2-4 : Driver Status Monitoring
- CED 3 : Collision Avoidance
- CED 4 : Cooperative Driving
- CED 5 : Autonomous Intelligent Cruise Control
- CED 6 : Automatic Emergency Call
- CED 7 : Fleet Management
- CED 9 : Dual Mode Route Guidance
- CED 10: Travel and Traffic Information Systems



P R O M E T H E U S

# Key autonomous car developments



## Into the 1990s

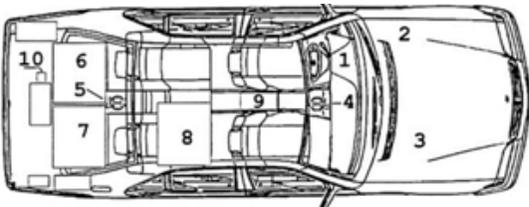
- Academia still leading the way – much developing from, or being wholly within, the arena of robotics
- Some collaborations between academia and industry developing, likely due to growing corporate awareness of the commercial application for 'spin-off' features – such as active cruise control and lane departure warning etc

As part of the Prometheus programme, and directly following the VaMoRos van, in 1995 Ernst Dickmann at Bundwehr University, and Mercedes Benz developed an autonomous S-class that could recognise road markings, its relative position in a lane, the presence of other vehicles, and judge whether safe to change lanes. It made a 1600 km return trip between Munich and Copenhagen, with speeds of up to 177 km/h, and only 5% human intervention on the whole trip.

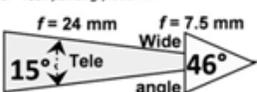
This car – as a development of the work in the VaMoRos van – set the template for subsequent camera based autopilot systems; it was the death knell for research still focusing on guided systems



Also part of the Prometheus programme was the Argo project run by the Universities of Parma and Pavia, which featured a modified Lancia Thema which could distinguish between traffic lanes, vehicles ahead and other interferences in its path, and was ran for 1950 km autonomously with a max speed close to 123 km in 1998.



- 1 electrical steering motor
- 2 electrical brake control
- 3 electronic throttle
- 4 front pointing platform for CCD-camera
- 5 rear pointing platform
- 6 Transputer Image Processing system
- 7 platform and vehicle controllers
- 8 electronics rack, human interface
- 9 accelerometers (3orthogonal)
- 10 inertial rate sensors



At distance  $L_s \sim 20$  m ( $\sim 60$  m), the resolution is 5 cm/pixel



In the US Carnegie Mello University roboticists drove NavLab5, a Pontiac TransSport from Pittsburgh to LA with only 1.8% of the journey requiring human intervention. Unlike European prototypes it had GPS



# Key autonomous car developments



## DARPA – an American approach

- › The DARPA Challenge is a competition for autonomous vehicles funded by the Advanced Research Projects Agency (part of US department of defence). Founded in 2004, and run on some subsequent years
- › The aim of these three challenges was to spur the development of technologies needed to create autonomous vehicles. The concept is a monetary prize to the winner completing a specific route fastest.

### 2004 Grand Challenge.

15 vehicles competed for \$1million prize to complete a 240km desert course – No cars completed - 'Sandstorm' from Carnegie Mellon University (a Hummer) travelled the furthest – 11.78km.

### 2005 Grand Challenge.

'Stanley' won, taking the \$2million prize money. Developed by Stanford Artificial Intelligence Lab of Stanford University (and stemming from autonomous work such as the 'Stanford Cart'), the car was a diesel Volkswagen Touareg and completed the 212km mountainous route at an average of 30.7kmh. Three other competitors from Carnegie Mello University, The Grey Insurance Company and Oshkosh Truck Corporation also finished.

### 2007 Urban Challenge

Using a 96km course simulating an urban environment with typical urban scenarios and competitors were monitored to check that they obey regulations.

Tartan Racing (Carnegie Mellon University and GM) in a converted Chevrolet Tahoe won at an average of 22.5kmh, the Stanford Volkswagen Passat were 2<sup>nd</sup>, Victor Tango (Virginia Tech and TORC Technologies) coming 3<sup>rd</sup> in a converted Ford Escape Hybrid.



# Key autonomous car developments

## Google arrives

- Google's 2009 arrival in the theatre of autonomous cars is significant; it signposted their intent to develop autonomous driving ('self driving' as then named) vehicles and thus the likely scenario that both the autonomous car will mature to a viable and ultimately ubiquitous product, and that the incumbent automotive industry is set for major disruption from this young, cash-rich successful company.

In 2009 Google began testing of autonomous cars with the Toyota Prius Sergey Brin and Larry Page (near camera) in the first Google car — a second generation Prius



Having completed 300k miles of highway testing with the Toyota Prius, Google shifts its autonomous car testing fleet to the Lexus RX450h in August 2012.

Later begins testing in city environments and develops its own prototype car (see following pages)

# Key autonomous car developments

Following Google's arrival, the incumbent car brands start to assert themselves

- › The formative autonomous car steps from Automotive OEMs came though following Google's announcement
- › These tended to be evidence of singular, in-house approaches (less so collaborative ventures with academic partners), at least in how they were commutated; they signalled a new 'brand-centric' approach to autonomous driving that put the car and the single user at the centre, not the wider infrastructure as before



May 2010: Audi and Stanford Robotic's 'Shelley' TT drives up Pikes Peak race course in the US with no one at the wheel

March 2013: Rinspeed XchangeE. Sit back, relax or just do nothing in the Swiss autonomous vision of the future



September 2013: Mercedes-Benz S500 *Intelligent Drive* drives Daimler CEO, Dieter Zetsche on to Frankfurt auto show stage

January 2014: BMW *Connected Drive* 'autonomous drift' car demonstrated at CES (Consumer Electronic Show), Las Vegas



# Key autonomous car developments



By 2014 the rate of development has become very fast

- › If the Google Prius was an important sign, then both the Google prototype and the Tesla S (and the Apple car rumours) were a major wake-up alarm: the autonomous car really is coming, it is coming soon and it is coming not-necessarily from the car brands we have known but from those cool Californian technology brands we have come to love...



May 2014: Google unveils its first in-house autonomous car design in prototype / model form — without steering wheel or pedals

October 2014: Tesla begins equipping Model S cars with the hardware (forward radar, forward-looking camera, 12 ultra-sonic sensors) to support autonomous driving



December 2014: Google unveils a development of the design first seen earlier in the year — its first fully functional, integrated prototype vehicle design — and begins on-road testing

Rumours about the car Apple is developing became rife in 2014; those in the industry knew that Apple was hiring automotive engineers and designers,...



# Key autonomous car developments



## Realisation of the autonomous experience

- Up until 2015 autonomous driving had only been experienced by a few engineers in controlled environments. In 2015 this changed; the Tesla Model S enabled public to travel nearly autonomously – and to hear about it!
- Several prototypes were used by brands on long autonomous trips to gain high profile media coverage that also aided this realisation that autonomous driving worked and was now available



January 2015: Major PR stunt for the start of CES 2015 — Audi's driverless A7 (known as Robbie) drives itself across California and Nevada, with journalists 'behind the wheel'

March 2015: Delphi (major automotive component supplier) built Audi Q5, completes autonomous coast-to-coast drive



October 2015: Alex Roy (author of 'The Driver') sets a high publicity autonomous/EV drive record time to cross America — 58 hours 55 minutes. Fastest ever 'level 2 autonomous' coast-coast time

January 2016: At Model X launch, Tesla CEO Elon Musk announces the much reported 'summon' — the next step in Tesla autopilot, allowing cars to be summoned to drive themselves across the country by 2018.



# Key autonomous car developments



Whilst the Californian tech companies wrote the headlines...

- Whilst the cool Californian tech brands were writing the headlines, 2015 was notable for the emergence of many steps forward from incumbent car brands, Volvo and BMW in particular. But whilst these had merit...
- Tesla increased their autonomous car capability (and their wider tech proposition) with over-the-air software updates and the autopilot functions this then enabled; by far the most significant AV advances in the market

January 2015: Mercedes unveils *F015 Luxury in Motion*; first modern auto OEM concept to be built around the idea of autonomous driving future scenario



August 2015: BMW 7-Series launches with keyfob-controlled autonomous parking – ‘Remote Control Parking (RCP)’ as they term the feature



October 2015: Volvo says it will accept liability for their autonomous cars involved in accidents — removing one of the greatest hurdles to adoption



October 2015: Tesla releases software version 7.0 — sending over-the-air (OTA) software update to Model S cars, enabling ‘autopilot’ functions



November 2015: Nissan unveils IDS — future autonomous concept with transformable interior environment for ‘driving’ vs ‘driven’ scenarios



November 2015: Volvo unveils ‘Concept 26’ — named after the average time (in minutes) of a commute in North America — shows interior set up for AD cars



# Key autonomous car developments



## China is coming, collaborations, deep learning

- › While Tesla, Apple and Google make the headlines, Uber and Chinese networks such as Baidu — now testing in China — could be the ones to truly upset the appcart
- › Auto OEMs rushing headlong into collaborations; meanwhile 'deep learning' is the next thing

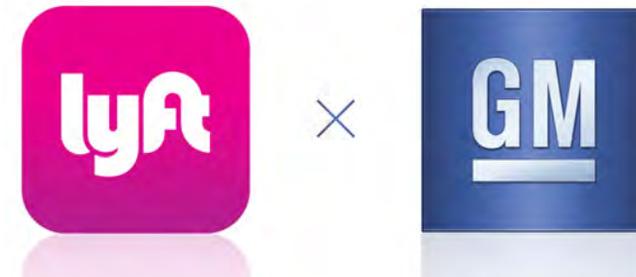
Uber has publically stated it will make its drivers redundant when autonomous technology is viable. Is now testing



GM has been hesitant about autonomous driving, but its new EV — the Chevrolet Bolt — is testing autonomous tech now



GM also partnered with Lyft — ride sharing company — to produce autonomous ride/car share. A trend



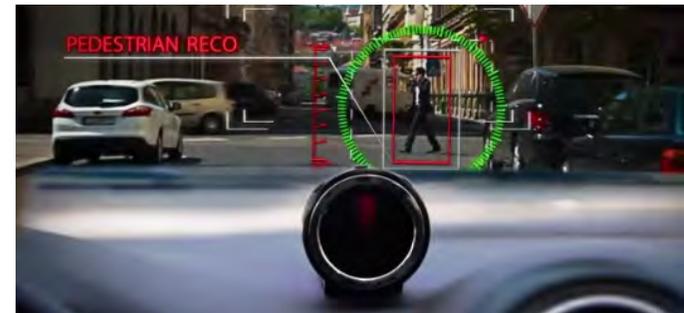
Chinese social network, Baidu is testing its own autonomous cars — one of many Chinese brands pushing this area



Toyota showed a demonstration of its 'deep learning' technology, which allows computers (cars) to learn and adapt

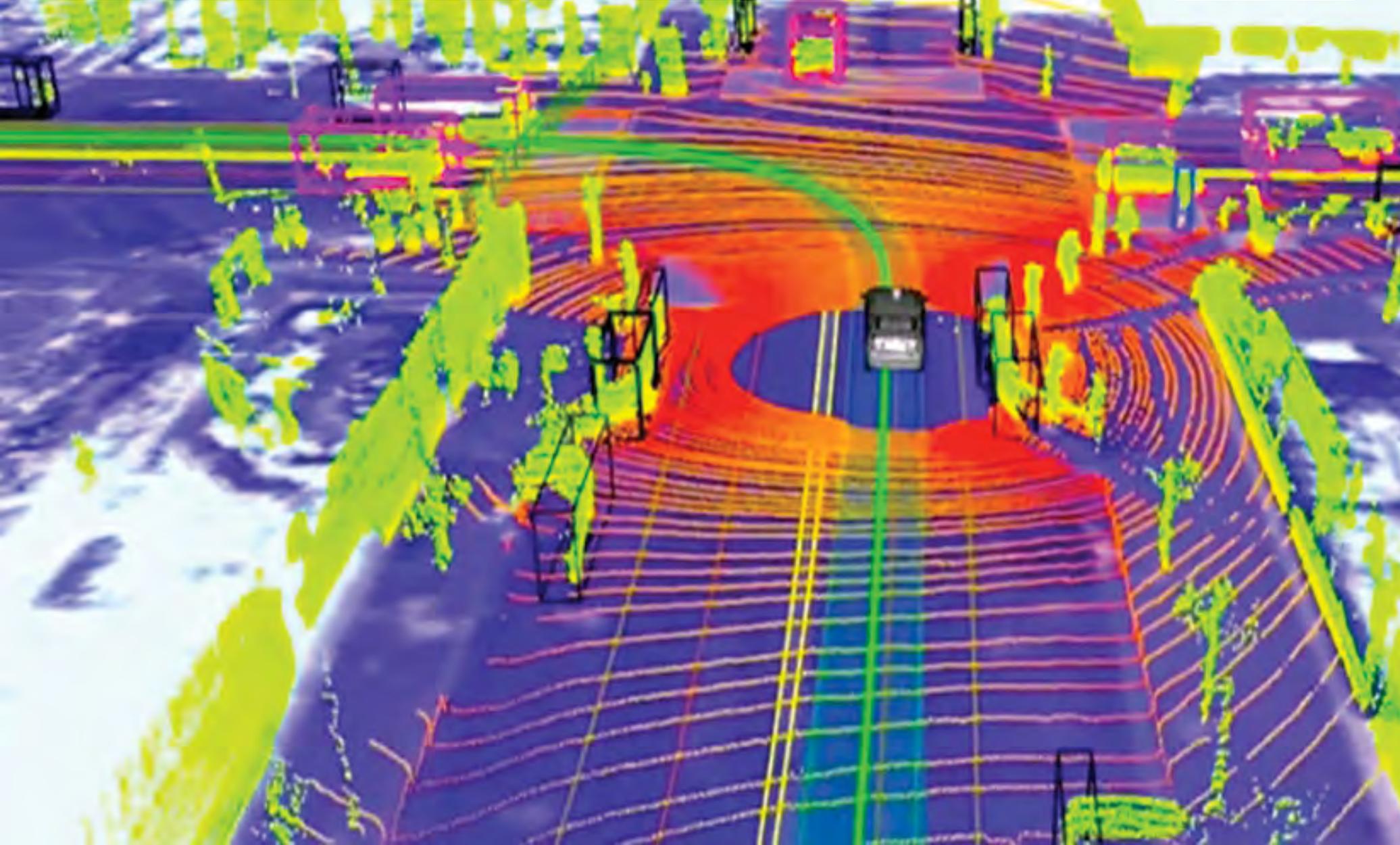


Supplier MobileEye is heavily pushing the idea of 'deep learning' — independent of autonomous, gives car eyes; learning



# Technical parameters

CDR



# Technical parameters

## Automated systems in cars – the prelude to autonomous drive

- Automated systems are technical features that actively take control over aspects of car's functionality, not those that assist (e.g. power assisted steering, electric windows) - they execute a driver or passenger's intent by controlling related but separate elements and or by responding to conditional changes; e.g.: changing gear when the throttle is depressed or engine speed reached, reduce speed after closing on a slower car



Automatic gear change is the most well known and established in-car automated system. It became widely adopted in the US in the latter half of the twentieth century and some other countries, less so in Europe.

Note how it may be taken as the identity of the car, e.g. "I drive an automatic" – potentially relevant to future autonomous cars

Cruise control – first seen on the 1958 Chrysler Imperial, was patented in 1945 as the "Speedostat".

Cruise control sets a speed that the car will maintain with varying degrees of throttle opening.

Automatic wipers - and automatic climate control and automatic lights - perform similar functions to cruise control within their respective feature realm; turn on the system and then it autonomously operates

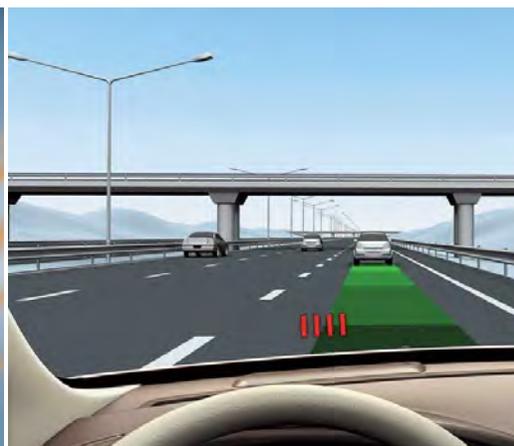


# Technical parameters



## Virtual proprioception

- Beyond automated functions in cars, many drivers have come to be familiar (even dependent) upon camera and radar based systems that given them a more informed understanding of where their car is relative to other other cars and nearby fixed elements, and enhance the safety of all road users



360 degree view and park assist with projected digital markings to guide the driver into a parking slot are now established in many premium cars – much aiding the driver in tight manoeuvres



Parking sensors, distance alerts, and blind spot warning systems use cameras and sensors and then (typically) light up a warning display when another car or obstacle is too close or in a blind spot. The warning flashes or a beep sounds if the drivers steers towards danger



Pedestrian detection is an emergent in-car safety system that aids driver awareness of pedestrians nearby

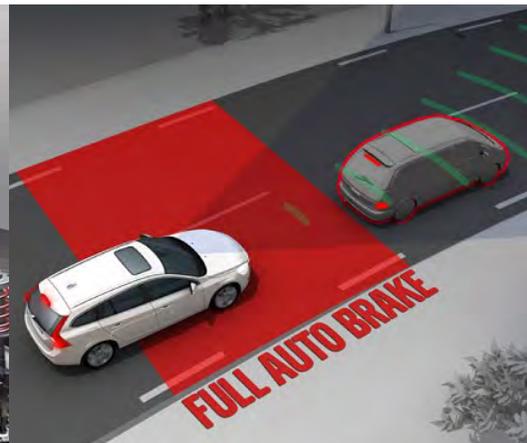
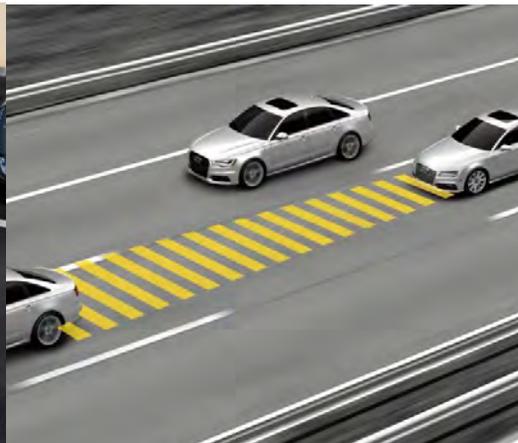


# Technical parameters



## Today's baby steps to autonomous driving

- › Within established and emergent automated systems are features that specifically take customers up to the edge of fully autonomous driving by offering some of the elements of autonomous driving
- › These are offered as discrete features or as part of a convenience or safety pack e.g.: 'active cruise control' and 'autonomous emergency braking'



'Auto parking' and 'blind spot warning' is likely to be the first exposure to autonomous driving many drivers experience. Toyota first introduced 'intelligent park assist' in the Prius in 2003.

The system can detect a parking space, and then with the driver still controlling accelerator and brake, the car automatically steers itself in.

Radar cruise control maintains a set distance from car in front and varies speed using throttle and braking

Lane keep assist reads white lines and adds (gentle) steering input to keep within a lane. This system was developed from lane alert which would notify with a sound, light or vibration (akin to driving over a 'rumble strip') that a white line is being crossed.

Auto brake [AEB] brakes the car if a driver doesn't when approaching a car in front. This will become a mandatory feature in Europe from 2018

# Technical parameters



## Classifying autonomy — the steps towards fully driverless

- › Autonomous driving is now becoming referred to based on a series of Levels from 0—4 in the US and 0—5 in Europe, where 0 is no automation and Level 4/5 is full self-driving automation
- › Currently, Level 4 vehicles are in test phase, while leading production vehicles (such as Tesla Model S) offer Level 2—3 type capabilities. Several Level 3 autonomous vehicles are expected to be on the road by 2020.

Available for consumer to purchase and use in many markets			Future availability (Level 3 cars likely 2018-2020)		
Today					
Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Driver only	Assisted	Partial automation	Conditional automation	Fully autonomous — within defined use case	Fully autonomous at all times
Monitored driving (driver needed at all times)			Non-Monitored driving available (driver is not needed at all times)		
Car does not assist driver in controlling vehicle	Car assists driver in some level of control (e.g. direction stability)	Car has control of brake/accelerator and steering in certain scenarios, driver must monitor	Car has control of brake/accelerator and steering in defined setting. Will ask driver to resume control in sufficient time frame	Car has full control of all system and does not need any driver intervention — within a defined use case	Car has full control always. No driver required

# Technical parameters



## Enabling features and technologies

- › Several key technologies and systems work together to enable autonomous functions
- › It is notable that a GPS chip, and positioning (only commonly available within the last decade) is a core enabling technology here.



EPAS (Electric Power-Assisted Steering) has become a standard feature on modern cars (replacing a hydraulic pump, fluid and motor to assist steering effort).

An EPAS system can be controlled by the vehicle's on-board computer systems — in other words it can steer instead of the driver

Over The Air (OTA) software updatability enable cars to be updated regularly in order for them to have up-to-date info on roads, traffic, etc - to be able to work autonomous.

Tesla pushed an OTA update to vehicles in 2015 that enabled autonomous functions

LIDAR (Light Detecting And Ranging) cameras are a key bit of autonomous car technology.

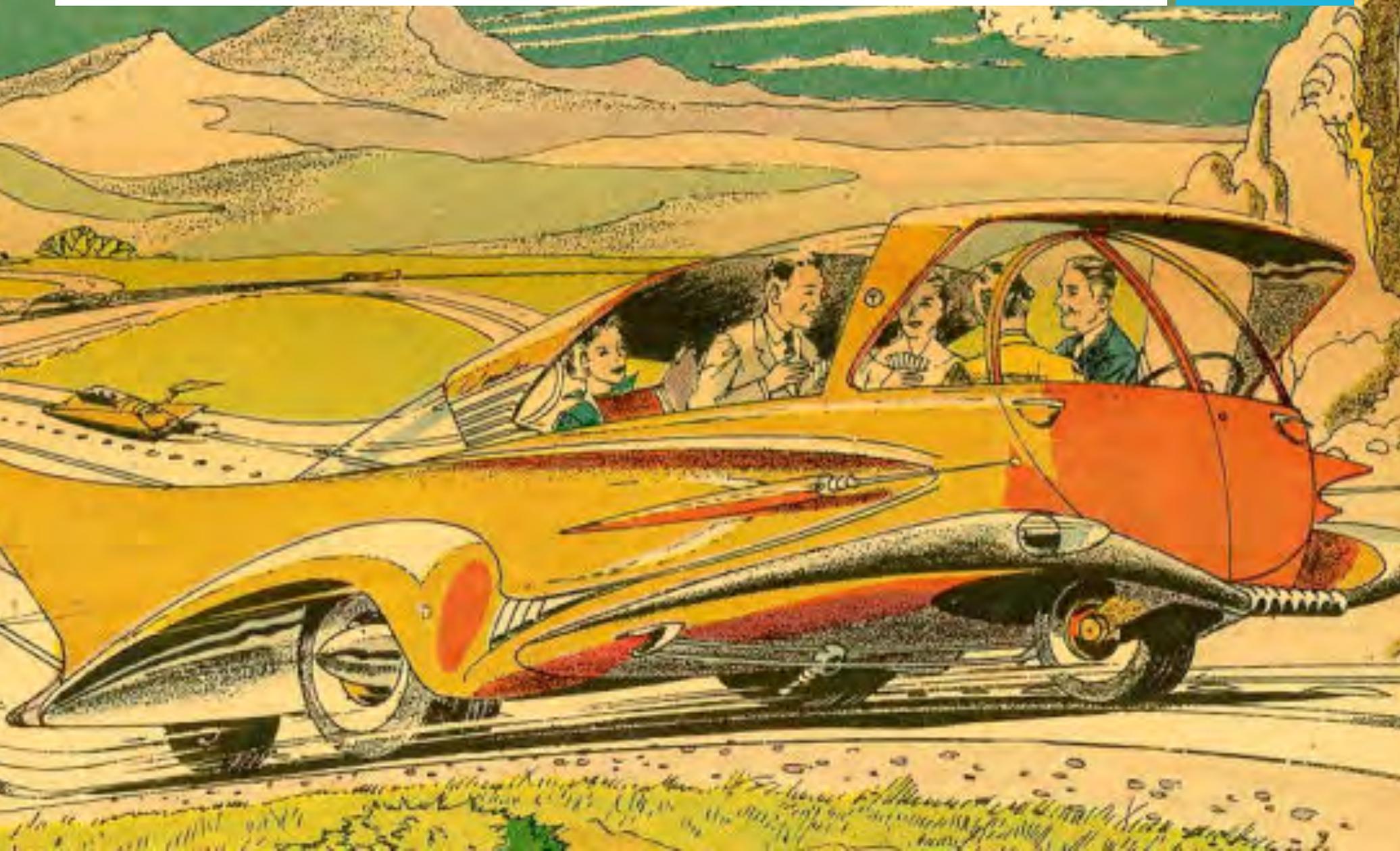
64 Lasers bounce 1.3 million pulses of light (invisible to the eye) per second off the car's surroundings to 'see' where road markings, road edges pedestrians and other cars are

Radar Sensors enable ACC (adaptive cruise control, a stage 1 autonomous car feature) by monitoring the distance to other vehicles.

There are two types; long and short range.  
Radar sensor on a current VW Golf pictured above

Cameras – usually mounted behind the rear-view mirror – monitor traffic lights, road signs and speed limits

# Socio-cultural consumption of autonomous travel



# Socio-cultural consumption of autonomous travel



## Yesterday's vision of the future

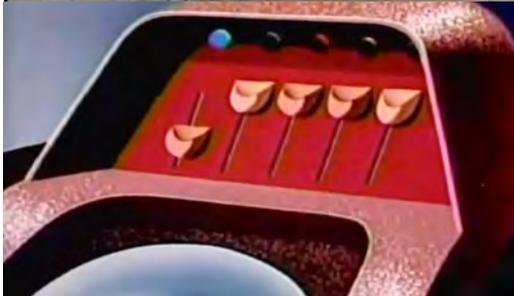
- Autonomous cars have been a long time coming — as long ago as 1939 in the Futurama World's Fair, the GM-sponsored transport section discussed the idea of autonomous travel, this continued through 1950s +60s
- This predominantly American vision was a popular and very positive part of the then wider socio-cultural positive view of a technologically progressed better future world



"Super highway of tomorrow" street intersection in the City of the Future; detail of the Futurama exhibit at the 1939 World's Fair



"Magic Highway, USA"; a 1958 animated episode of the Disneyland TV programme depicted autonomous cars in the US. *"As father chooses the route in advance on a push-button selector, electronics take over complete control"*.



This film, by GM, from 1956 featuring the Firebird II concept, envisaged the roads of tomorrow (for 1976) — surprisingly similar to much of what is proposed today



# Socio-cultural consumption of autonomous travel



## Advertising and visions

- › Reflecting technological development – particularly in aviation and electronics – many media depictions of the future embraced the driver-less car concept as a central part of future life in developed societies
- › These adverts and media depictions of driverless cars bare close resemblance to the GM and Disney visions from the previous page and depict the autonomous driving idea much as it remains today

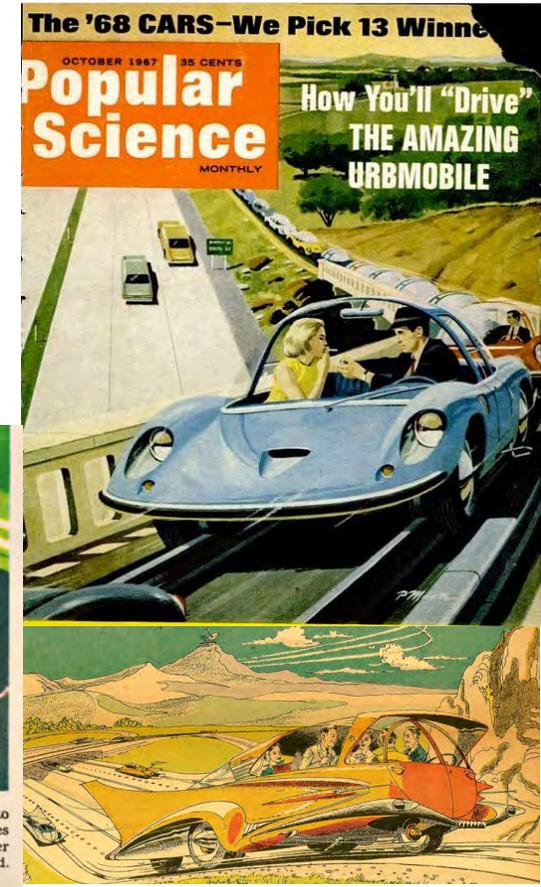


1956 advert from a US Power Company, of a family playing a board game in their car driving on an autonomous highway

January 1956 illustration from 'Everywoman's Magazine' based on the film 'People, Products and Progress – 1975' produced by the Chamber of Congress of the US government



The automobile of 1975! If it seems driver is not paying attention to the road, he isn't! Electronic guidance and obstacle-warning devices will keep car under control as it flashes at ultrahigh speeds over superhighways. Cars will be lower, larger, probably atomic-powered.



# Socio-cultural consumption of autonomous travel



## Film visions of the future

- › Films have shown a significant influence on the collective public imagination when it comes to new ideas, and many futuristic films have — for a long time — portrayed visions around autonomous travel.
- › Many heavy-weight science fiction films and also popular TV — Night Rider and Mr Bean - have also significantly influence the public perception of what an autonomous car will be



1927's Metropolis was one of the earliest films to envision sky-scrapers, cities in the sky and partially automated roadways and travel — controlled by a separate section of society.



More contemporary (and often car branded) visions include 2004's iRobot (above) and 2002's Minority Report (below)

The world's favourite driverless car is KITT — from the TV series Knight Rider. A 1982 Pontiac Trans AM with artificial intelligence and self-driving capabilities



## Autonomous Race car series

- › In vehicular history, motor racing has always been a leader — for the introduction of technologies which trickle down into production vehicles, and for pushing boundaries and generating brand value/followers
- › The proposed 'Roborace' series, announced in early 2016 with car's such as the below designed by former VW designer and Hollywood Movie car design, Daniel Simon, could be a significant step in autonomous history



# Socio-cultural consumption of autonomous travel



## Modern media consumption, creation and dissemination

- Today most people's view on what an autonomous car is/will be, how it might affect them and what the future looks like are formed by media.
- This is not just being driven by the technology media's 'pro-autonomy' stance, but social and consumer-generated media around Tesla's autopilot technologies, and mass-media's desire for headlines

At the start of May 2016, social media was a wash with these images of a man supposedly asleep at the wheel of his autonomous driving Tesla, in California



Google has made significant use of in-car video footage of test users, experiencing its steering wheel and pedal free driverless car concept.



MailOnline

Home | News | U.S. | Sport | TV&Showbiz | Australia | Femail | Health | Science | Money

Latest Headlines | Science | Pictures

### When Tesla's autopilot goes wrong: Owners post terrifying footage showing what happens when brand new autonomous driving software fails



When Tesla released its autopilot software, numerous videos of 'near miss' situations were posted by owners — which Tabloid media picked up on

# Potential next steps — research opportunities



# Potential next steps — research opportunities



## User expectation, experience and exposure

- › Exploration of user expectations (and misconceptions) about autonomous cars and patterns of reaction around first exposure to fully autonomous cars.
- › Understand user experience of Level 1 and 2 autonomous systems, available in current production cars (e.g. lane assist) — how might this inform needs and patterns for Level 3 and 4 autonomous vehicles.

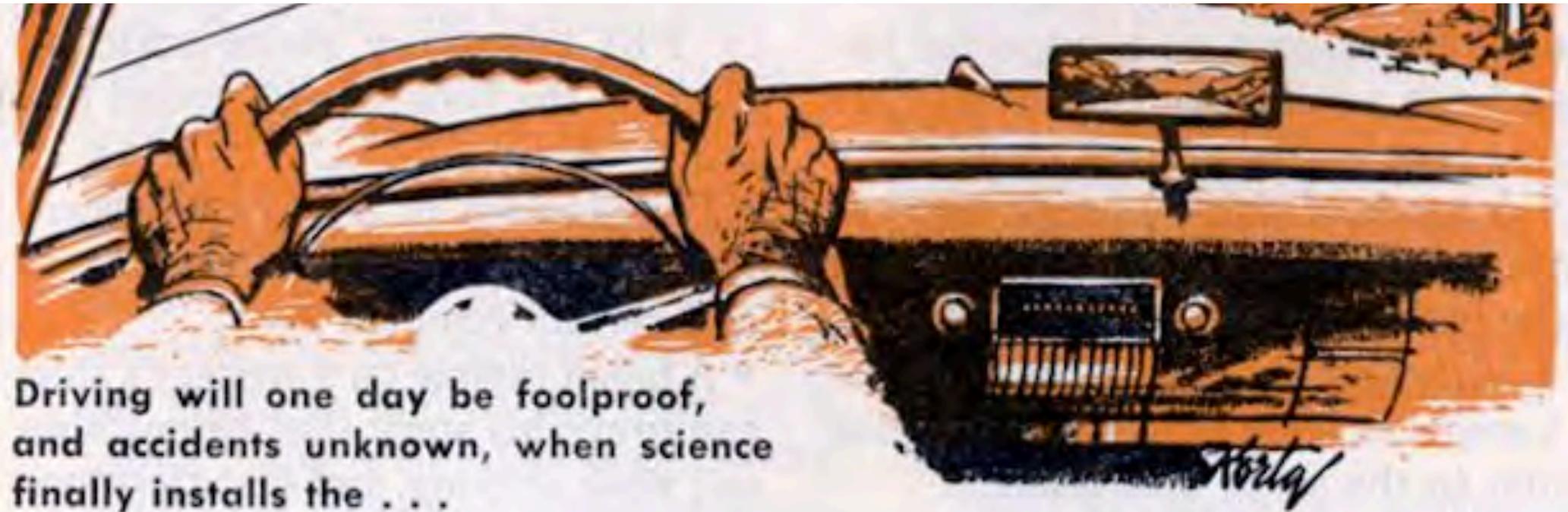


# Potential next steps — research opportunities



## Communications strategy

- › How autonomous car features and benefits could be best communicated to drivers and potential future customers — to inform them through communications and to (potentially) stimulate demand.
- › Understand what the barriers are currently within users' minds, how to maximize benefits, and how to present features/concepts in an understandable way.



# Electronic Highway of the Future

# Potential next steps — research opportunities



## The transition zone

- › For level 3 autonomous systems, a challenge is the transition when the car hands back control to the driver
- › What can be learned from analogous systems (e.g. Airline autopilot) and what problems do these create
- › How do customers respond to different requests to take back control, how long does it take them to cognitively engage and how do different system affect reaction time/attention levels?



# Car Design Research Overview



# Car Design Research Overview



We help our clients create commercially more successful designs

Founded in 2001, Car Design Research is a consultancy that works in the space between design, product planning and marketing – typically on future facing programmes.

Our four core areas of work are:

- › *Perspective*: an external view on client brand, design and product issues
- › *Intelligence*: exploring best practice and emergent trends in design, car design, society, technology
- › *Strategy*: working with the client team to create robust and exciting future brand, design and product strategies, and to help them realise this with management and creative stakeholders
- › *Communication*: helping communicate the value of design internally and externally

Recent clients include:



Audi



HYUNDAI



CHERY



RENAULT



TOYOTA



NISSAN



mazda



LOUIS VUITTON



RTT



Disney



KPMG



sabic

# Car Design Research Overview



## What some of our clients think



*"For several years I've much valued close support from the team at Car Design Research. Most recently they have worked with me to create key design management tools for Kia and Hyundai that will enable us to consistently differentiate our brands and elevate the contribution design makes to our business. Some agencies deliver useful research, some have expertise in the automotive sector, and a few get car design; in my opinion CDR is unique in having all three of these things."*

– Peter Schreyer, Chief Design Officer, Hyundai, and President and chief design officer, Kia



*"Car Design Research worked very closely with me to develop a new Design Strategy for Volvo cars that we're rolling out now. Their work was clear and visually strong for us to use in Design, but also had the commercial substantiation valued by our management team"*

– Thomas Ingenlath, Vice President of Design, Volvo



*"When we needed a credible and knowledgeable outside point of view, we naturally turned to Car Design Research. Their vast knowledge of all things design, experience in the field and network of design professionals establishes them as a reference point for car companies."*

– Laurens van den Acker, Senior Vice President of Corporate Design, Renault



*"CDR provided Nissan Design Europe with insights, trends, and nuanced analysis from a Design perspective. They also helped us connect with Creative agencies and facilitate collaboration with Design-led institutions that we could not have easily accomplished."*

– Victor Nacif, previously Design Director Europe and Global Head of Product Communications, Nissan



*"What makes the research work of CDR unique is that they understand design and have a passion for it. It allows them to create studies and insights that resonate with designers and make sure that what they do is a real added value to the creative process."*

– Lowie Vermeersch, Director GranStudio, Previously Design Director, Pininfarina



