Automotive **Engineer**

Technical Update

NOVEMBER 2013

Welcome to the November issue of the Automotive Engineer Technical update for IMI Certified Automotive Engineers (CAE) and Advanced Automotive Engineers (AAE).

In this issue, we discuss the future of self-driving vehicles and the technology behind them.

Self-braking, self-steering – but vehicles that can **drive themselves?**

Everyone has or will come across driver assistance features as fitment rates increase exponentially on new cars, and many of the systems have a range of technologies. However, whilst the next step to self-driving vehicles is technologically possible, just how big a step is it for society to take?

Let's start with a re-cap of the building blocks from which a system capable of either assisting a driver or even driving a vehicle without human intervention can be built. There are three technologies that vehicle manufacturers have settled on to provide an array of active safety devices – radar, infrared and optical. Each already exists in highly sophisticated forms within the Military for example, where the cost of such systems is not really as price critical as it would be for the automotive industry.

Optical object classification:

The advent of 'Complementary Metal–Oxide–Semiconductor' (C-MOS) devices brought optical object recognition within grasp. The sensors can be 'just' cameras or they can measure distance to the perceived object. The basic device is able to recognise road markings and alert the driver should the vehicle pass over the markings without activating the indicator. However, this is merely the start.

The camera systems transmit a chopped form of light (modulated light) which, as it collides with an obstacle, is reflected – thus providing a position relative to the vehicle as well as relative speed of the obstacle. That data is mapped onto a pixelated map, from which the camera can then report a 3D image to the controller. The controller in turn has a range of obstacle 'master' forms, which it can compare to the information received from the camera. The speed with which this occurs allows the controller to map and track obstacles, to differentiate between the back of a truck or the side of a truck, or to decide if the object is mobile or static. Since the slowest part of the system – the electrons – move at about one third of the speed of light, the whole process is effectively instantaneous to mere humans.

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The C-MOS camera based obstacle recognition system maps obstacles – each pedestrian is framed by a line which allows the system to categorise the type of obstacle and then track each potential obstacle. © Volvo Car Group AB

To give an idea of the complexity, it has to process observed images into the following categories: cars (560 variations), trucks (168 variations), pedestrians (503 variations), traffic signs (353 variations) and other objects (120 variations).

Stereo CMOS camera technology:

First to market was Subaru in 2010, although only in the domestic market. Two cameras set in the same module are able to take two views of an obstacle, classify it the same way but between the two views calculate the position ahead of the vehicle. This process is called triangulation, and with CMOS cameras it is limited to daylight operations only.

© Fuji Heavy Industries

Infrared sensing (night vision):

These systems allow an enhanced image to be presented to the driver when driving at night. The system is optical and does not work too well in misty conditions – indeed the best place for the camera is behind the swept area of the windscreen. The application to the right is fixed behind the front grille, and has its own washer jet to keep the lens clean. The image is either projected onto the inside of the windscreen or is displayed in the instrument cluster. Such systems have been around since 2001, and as a stand-alone device it has limited appeal. Here is the infrared camera system fitted to the Audi A8 (D4) upper grille – note the washer jet for the lens.

© Audi AG

RADAR:

Radio Detection and Ranging (RADAR) is one of the current means to measure distance. How does RADAR work? A transmitter sends out electromagnetic waves which have a certain frequency. If these waves collide with an object, a modified form of the wave is reflected back to a receiver, which given the shift in time base can be used to calculate distance. The automotive sensor has the transmitter and receiver built into a single module:

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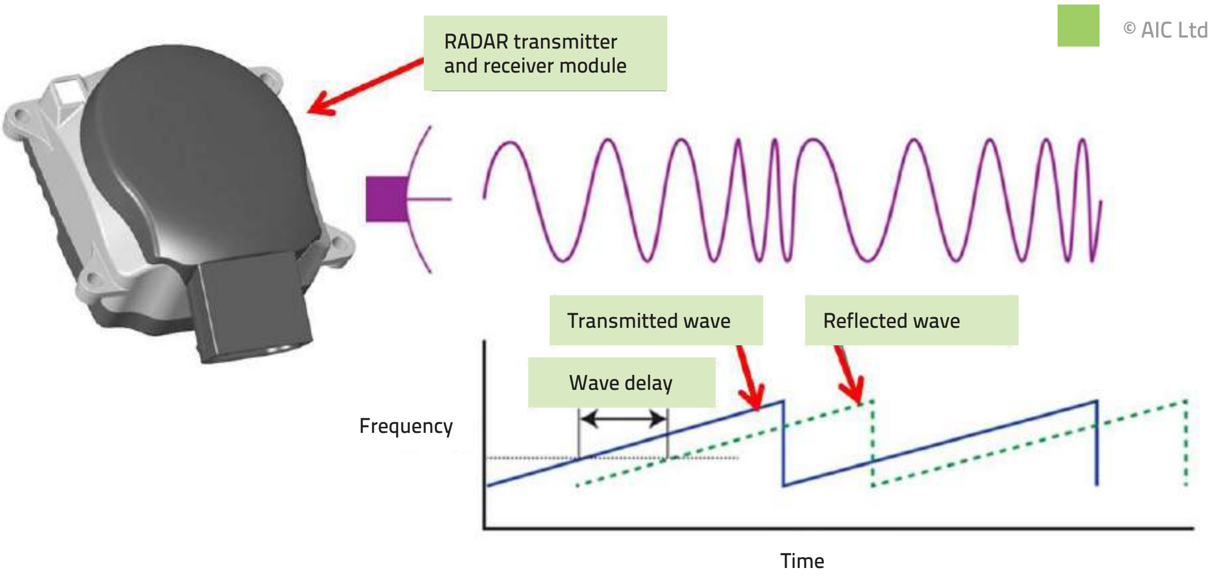
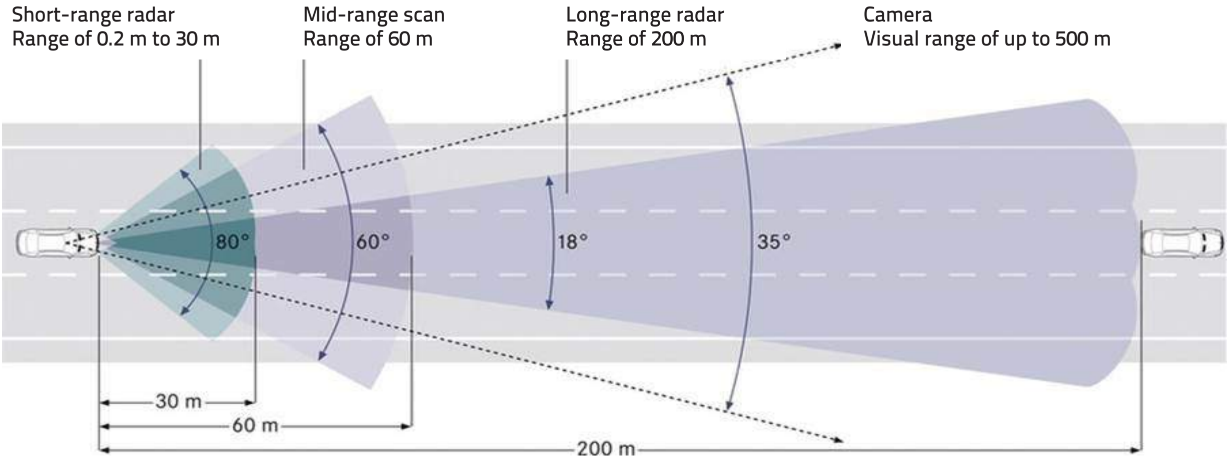


There are two dominant technologies – 77 GHz and 24 GHz. These transmission frequencies were reserved for use by vehicles around the world, so preventing the electromagnetic wave frequencies from being used for other broadcast purposes.

RADAR (continued):

77 GHz units tend to be used for forward facing long range RADAR system which has a 200m range (accuracy within 0.75m), working at speeds of up to 136 mph (accuracy within 0.1 mph). The system can work at a maximum relative vehicle speed of 136 mph or 2.2 miles per minute, so is able to see around 4 seconds ahead. That means up to 136 mph relative to a fixed object, or two vehicles approaching each other with a closing speed up to 136 mph. The scanned area is around 9 degrees either side of car centre line (18 degrees included angle).

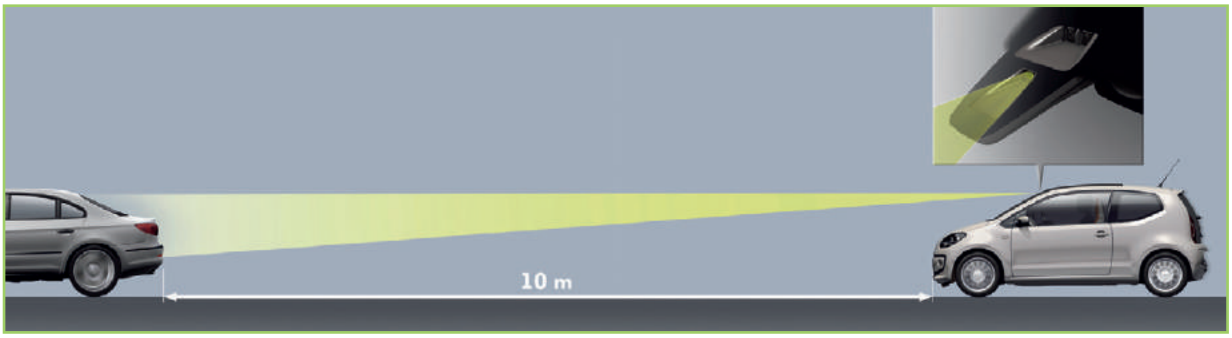
24 GHz units can also be used for forward facing RADAR systems. These tend to be used for side / blind spot obstacle detection, and is correspondingly less powerful than the 77 GHz unit – the range is 60m but the measurement zone is 30 degrees either side on car centre line (60 degree included angle). These units tend to be used in conjunction with the long range radar unit to provide greater spread of surveillance closer to the vehicle. A unit with even less field depth (around 10m) but a much wider sensor angle (120 degrees included angle – or more) is used for rear mounted blind spot detection.



Robert Bosch GmbH

LIDAR:

Light Detection and Ranging (LIDAR) uses a laser light source to measure distance via a similar method to RADAR or via a Doppler effect. Both systems require transmission of a laser light source, and detection of the reflected light to measure distance. Typically such sensors are fitted behind the windscreen, pointing forwards and measuring around 10m ahead of the vehicle.



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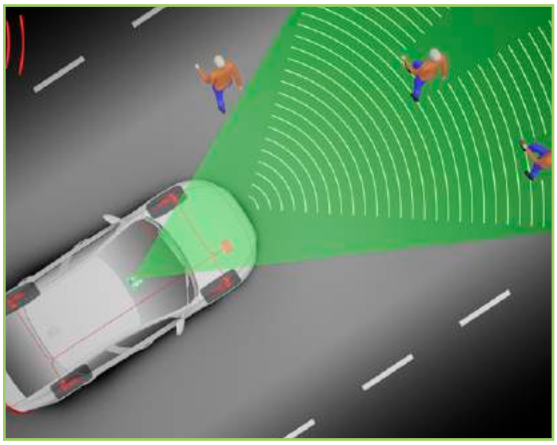
The network - putting it all together

The advent of ABS, Electronic Stability Control (ESC), powertrain management systems, electric PAS and adaptive damping has occurred over many years along with computing power which has increased with each new model generation. The big step is now linking these modules into a vehicle wide network. Consider if just two of these systems are present on a vehicle – ESC and electric PAS. The vehicle can, when equipped with some or all of these sensors, alter the speed and direction of the vehicle without driver input. ESC was required to be fitted to all new model types sold in the European Union from 1st November 2011 onwards, and all new vehicles sold in Europe must comply by 1st November 2014. Currently there are no plans to make active safety systems a legal requirement, but one can see that mass adoption of ESC (fleet, impending law) and electric PAS (fuel economy reduction) could make this possible.



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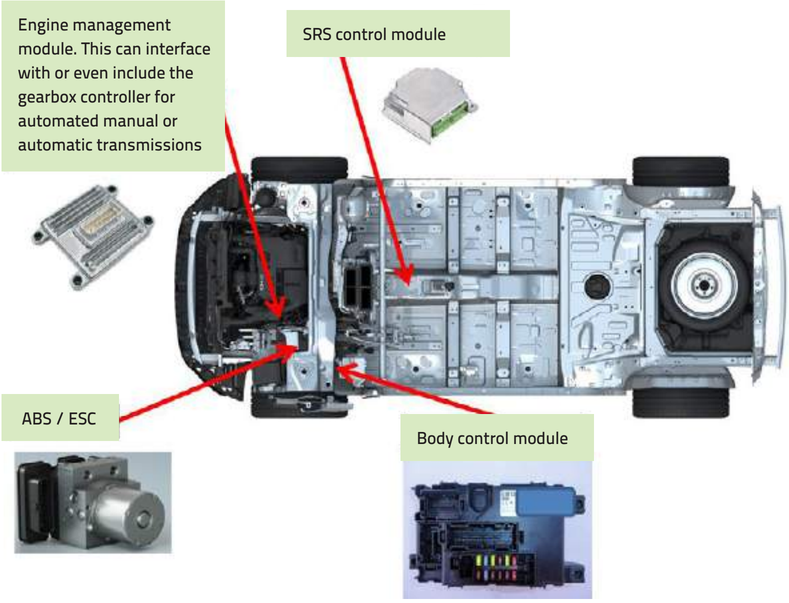
Shown above is the Volvo CitySafety system, with the RADAR unit detecting obstacles (fixed behind the front upper grille), the camera based system (fitted in a module - along with rain sensing as well as light sensing - on the windscreen), categorising those same obstacles as well as tracking them. The controller calculates the risk of collision based on this data, and if the driver fails to notice, it will activate the braking system, bringing the vehicle to rest at speeds below 18 mph. The Volvo system also has a laser-based system to sense what is happening 10m ahead of the vehicle, also included in the windscreen mounted module. The combination of long range RADAR (shown by the white bands in the above picture) and optical sensing (shown by the green shade) – the two systems work together to calculate position relative to the car and to classify / track the potential obstacle.

Indeed it is this array of sensors that provides significant capability when acting as part of a system, so mitigating the limitations of any one technology. However, technology is already moving on and soon camera-based systems may eclipse the need for RADAR sensors.

As a reminder, these sensors work together with the following systems:



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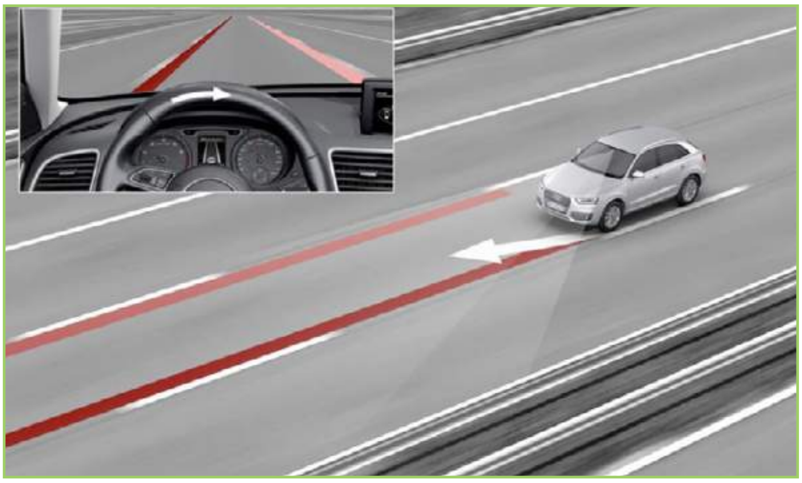
Lane keeping

The e-PAS system allows the vehicle to self-steer the front tyres up to 3.5 degrees either side of straight ahead. Using the C-MOS camera, the system detects the lines painted on the road surface. As the vehicle drifts across those lines, an alert is given to the driver and some systems will steer the vehicle to stay in the lane, unless the indicator is used which cancels the system activity.



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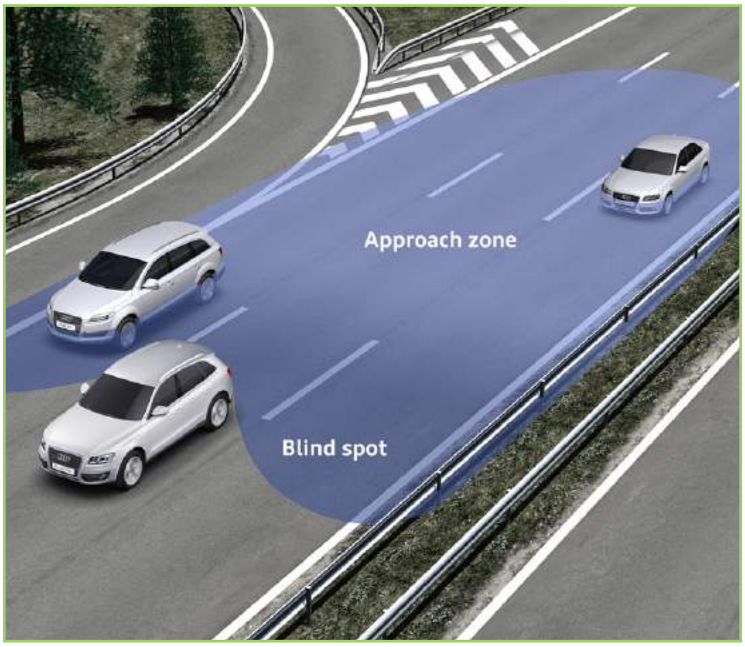
Blind spot detection

The door and interior mirrors provide excellent views around the vehicle except for a few dead zones, known as blind spots. Until recently this was a real problem countered only by a driver looking around to double check. The systems developed to assist the driver typically have two or even three RADAR sensors to scan the rear end of the vehicle, and more recently, rear view camera technology has evolved to provide assistance (first introduced on the 2013 Nissan Note).



When a potential collision is detected, the driver is alerted by a warning light in the door mirror, or on the interior trim near the door mirrors. Some vehicles (Volvo for example) used camera technology in the door mirror to detect obstacles which worked well except in rain, when road dirt build-up reduced the effectiveness of the system. For this reason the 2013 Nissan Note rear view camera has a special air jet based cleaning system, which it can deploy if the image has become dulled by road dirt – an example of what 4 years of continuous technological development can bring.

© Audi AG

Self-parking

Introduced from 2008 onwards on selected Volkswagen group and Lexus models, the system offered automated parallel parking. With the advent of even better software and access to more sensors, automated parking today can park a vehicle in almost any position. The core technology is engine control by wire (initially the driver remained in control of the engine speed), electronic control of the power assisted steering and a range of ultrasonic sensors fitted to the front as well as rear bumpers.

The vehicle has side facing ultrasonic sensors which detect an open space. The system then calculates the best path to place the vehicle in that space, using the parking ultrasonic sensors as well as the side facing ultrasonic sensors to avoid collision with surrounding objects. Once the driver has selected reverse gear, the system knows how much steering lock is applied via the ESC steering wheel angle sensor, applies the appropriate engine speed and can control the braking system via the ABS module. All the driver has to do is sit – the driver can override the system at any time by holding the steering wheel, applying the brakes or using the accelerator pedal.

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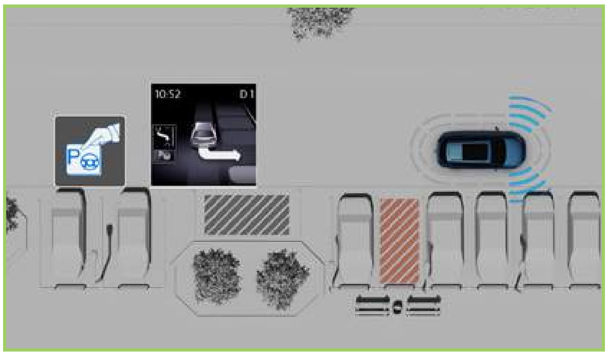
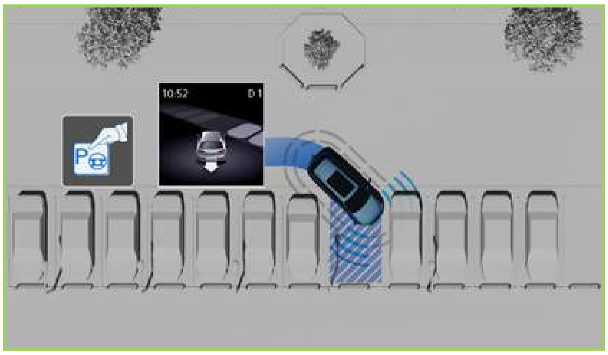
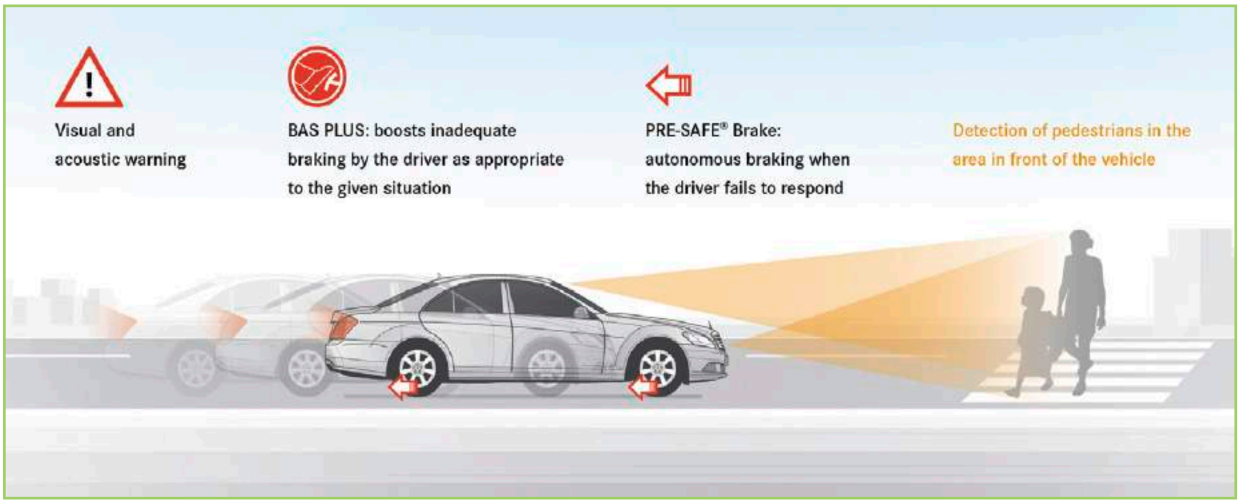




Autonomous braking and adaptive cruise control

Depending on what type and how many sensors are fitted to a vehicle, they work seamlessly with the brakes, SRS and (now) steering to help avoid accidents. The range finding sensors combined with object classification feed data to the ESC system, which can then calculate one of several thresholds, taking into account the weather conditions:

- Driver alert – the system has detected an obstacle and predicts there will be a collision unless the vehicle is either slowed down or changes direction. Use of the windscreen wipers will alert the system to wet road conditions and alter the calculated braking distances accordingly. The driver is given both a warning light as well as an aural alert.
- System preparation for an accident. The driver has not heeded the warning, and so the vehicle will increase the line pressure in the braking system to reduce the response time by around 30 milliseconds, close the windows as well as sunroof (if fitted) and arm the SRS. Alarm signals are still sent to the driver.
- Point of no return. The driver has failed to respond, the danger still exists and the point at which the brakes should be applied to miss the obstacle approaching. The vehicle does so, and in the process will either miss the obstacle or hit it at a greatly reduced speed – at which point the SRS will be deployed.
- Latest versions of the system can also apply small steering corrections to avoid obstacles.



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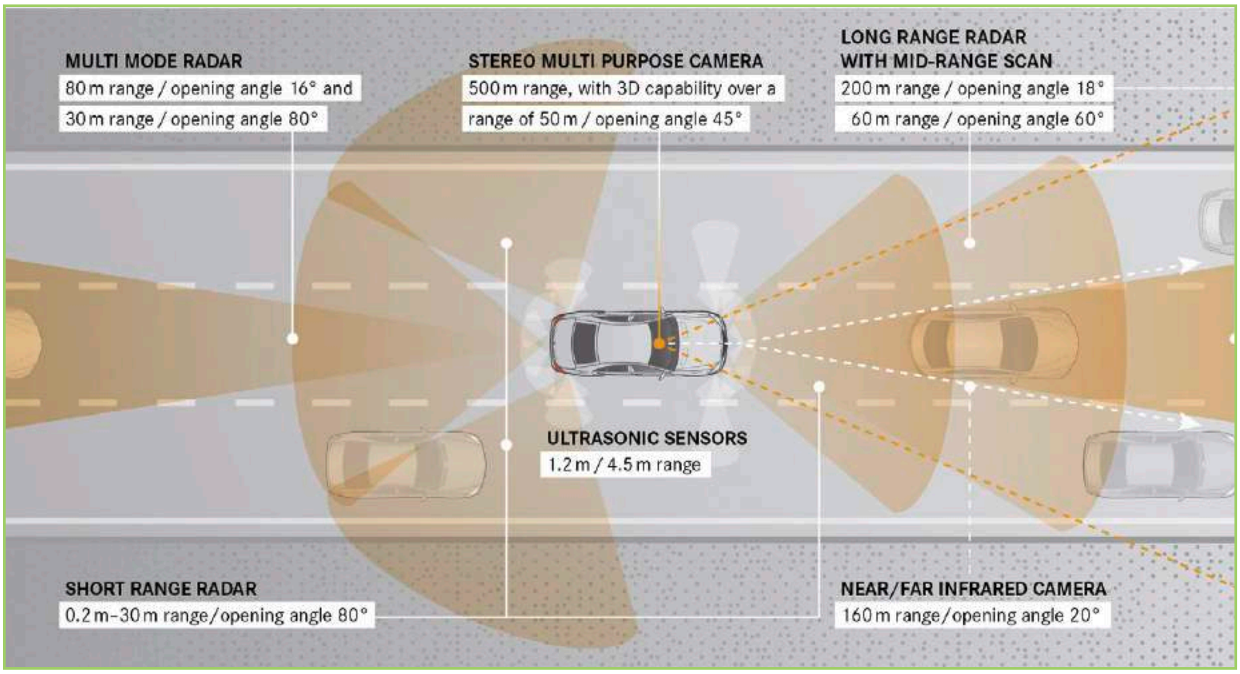
To achieve this performance the vehicle uses data from all available sensors to assist with the accident avoidance strategy.

A similar approach is used with adaptive cruise control. The vehicle speed is set, but as the RADAR units detect a slower vehicle ahead, it will reduce engine power and, if necessary, apply the brakes to match the speed of the slower vehicle. As the vehicle in front speeds up or slows down , so the adaptive cruise control vehicle follows the same speed up to the pre-set maximum. The system is so flexible it is possible to drive through dense rush hour stop/start traffic with the limit set to 70mph, where upon reaching a motorway and as traffic clears, the target speed is reached, all without touching the brakes or accelerator.



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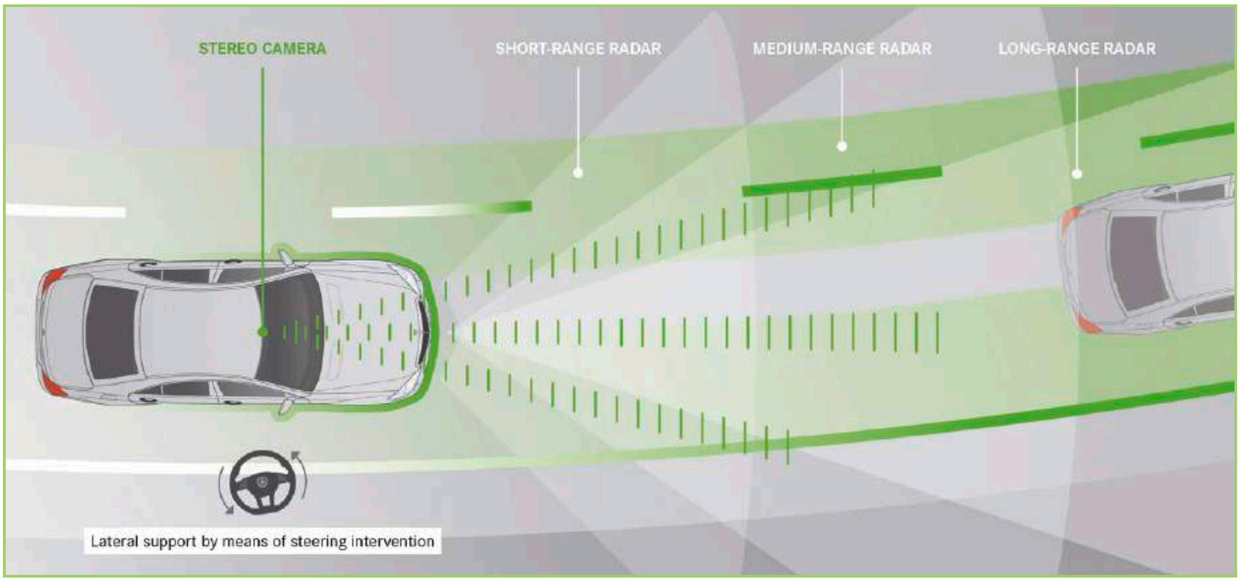
The sensor array for the 2013 Mercedes-Benz S class W222 has no less than 7 RADAR sensors, 2 C-MOS cameras and LIDAR too. The system can use the limited steering correction possible under present law along with the braking system to avoid accidents even on a bend:



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Telematics

The primary aim is to establish two-way wireless communication with a vehicle. It is already widely used in the passenger service vehicle and heavy truck markets to communicate not only driver behaviour but also the daily record of how long a driver has worked. Currently there is no standard defining what should be communicated, and the technology is hampered in the UK by the lack of 4G LTE technology – although from the start of 2013 this changes as it becomes available, so increasing the real time data transmission capacity by 10 to 20 fold compared to 3G.

Car to car and car to infrastructure communication: The aim is to hook up vehicle drivers to both pedestrian movement as well as things like traffic lights. Many research projects have been commissioned all over the world from Governments, vehicle manufacturers and wireless technology system providers. There is no agreed protocol on how such systems might work, in that they require a way to alert the driver or ultimately brake or steer the vehicle. This is clearly a bridge technology between telematics and autonomous vehicle functions.

Autonomous braking and steering: The advent of electrically power assisted steering as a widespread fitment on many new cars from 2003 onwards (the honour of the first production system goes to the MG F and the Honda NSX auto) combined with ultra-sonic parking sensors and electronic engine control enabled autonomous parking systems to be offered as relatively small on cost. The advent of ESC becoming a requirement for all new cars sold in many parts of the world (led by the USA), enabled further integration. Add a combination of optical object classification along with laser-based and RADAR-based distance measurement devices, and we have the capability to alert the driver or take over. The systems are not possible for the moment to retro fit, except where a vehicle was engineered with such an option during its lifetime.

Self-driving cars - **is there a future?**

Much has been published in the automotive press about vehicles which can drive by themselves, as an indication of the future. Competitions have been running around the world for such vehicles for more than a decade, and in the past few years selected states of the USA have issued licences to operate driverless cars – mainly to Google. So surely this is all going to become fact? Not quite – or at least, not for quite some time. Some building blocks are required for successful driverless vehicles:

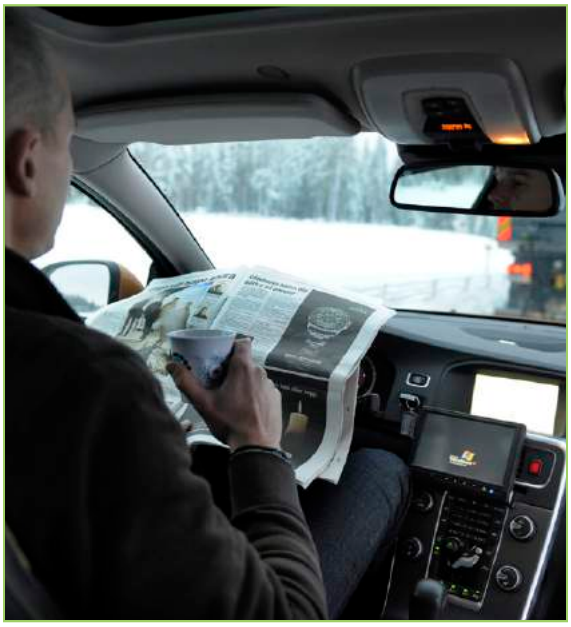
Firstly, a reliable global positioning system combined with 3D mapping is needed to allow the vehicle to apply the right power / braking / steering. Existing GPS based systems can position to the nearest 5m by 5m square, but there are competing systems from Russia as well as Europe too. Large companies such as Google have spent many a happy month painstakingly mapping the world street by street to make satellite based positioning technology even more powerful.

Secondly, vehicles will need to be equipped with the means to communicate with other vehicles as well as fixed structures such as traffic lights. In this way a vehicle could detect the intended path of an unseen vehicle and take appropriate measures to avoid a collision.

Thirdly, the biggest demand. All of this needs to be proved capable of performing with power interruptions, major electric storms, and most significant of all – a huge number of users.

All of the required technologies have been demonstrated around the world in publically-funded research programmes, whilst the biggest building blocks – the technology to enable autonomous braking (ABS, leading towards ESC) and small steering corrections (electric or electro hydraulic PAS) have become legally required fitment in many global markets.

However there is a big leap of faith to driverless cars. The biggest obstacle is not technology but strategy – why provide this capability? For mass transportation in inner city / urban spaces, dedicated railways or trams make much more sense and are much more energy efficient. For intercity travel, again either railways or aircraft are viable alternatives to 'driverless' services. Will it happen? Probably yes, with limited introduction intended for lower risk usage (on motorways / interstate highways for example), and depending on the rate vehicle to infrastructure communication takes off, it could be extended into the cityscape itself.



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The road blocks?

Government and insurers. Much has been presented about active safety systems, from vehicles assisting the driver to mitigate impending disaster through to vehicles that can drive without a driver. Such research projects have been generously funded by Governments all over the world since the idea would seem to go some way to eliminating road casualties. That in turn leads to significant economic savings due to reduction of victim support, reduced emergency services costs and more besides. The biggest step of all is understanding the system risks, the probability of those risks happening and what can be done to minimise those risks. That in turn produces a debate not centred on technology, but how technology can serve us.

Questions:

1 What does the term C-MOS stand for?

2 Where can this type of device be found apart from cars?

3 What does RADAR stand for?

4 How does RADAR measure distance to an obstacle?

5 What are the typical RADAR broadcast frequencies?

6 Why is it important to only use specific electromagnetic wave broadcast frequencies?

7 What does LIDAR stand for?

8 How does LIDAR measure distance to an obstacle?

9 What is the range and accuracy of LIDAR?

10 How is the vehicle brake system controlled electronically?

11 How could the steering be controlled electronically?

12 Is there a limit to the steered wheel angle?

13 Why does a vehicle need to receive or transmit data?

14 How does this data transmission fit into autonomous driving?

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