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ADAS Sensor Market Landscape

After more than two decades of active safety development and deployment, the market for advanced driving assistant systems (ADAS) is becoming mature, especially in Europe and in the USA.

Initially, most ADAS were introduced as a one sensor one feature approach, but with increasing systems performance requirements this approach has reached its limitation. Combining the strength of different sensors together is becoming more common. This is particularly true to the more advanced systems available today.

This report provides an overview of the capabilities of each sensor technology (radar, camera, lidar and ultrasonic), identifying various types within each technology, their pros and cons as well as assessing their suitability to support increasing levels of vehicle autonomy. Robustness, detection and classification capability of each sensor type are explained together with OEMs sensor fusion strategies, Tier 1 offerings and latest developments. Finally some market forecasts are provided.

COVERAGE	FREQUENCY	PUBLICATION FORMAT	PAGES
GLOBAL, NA, CHINA, EUROPE	ANNUALLY, QUARTERLY, ONE-OFF	PDF, POWERPOINT, EXCEL, ONLINE	130+

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Key features & benefits

- This report provides an overview of the capabilities of each sensor technology (radar, camera, lidar and ultrasonic)
- Identifies various types within each technology, their pros and cons as well as assessing their suitability to support increasing levels of vehicle autonomy
- Robustness, detection and classification capability of each sensor type are explained, together with OEMs sensor fusion strategies, Tier 1 offerings and latest developments

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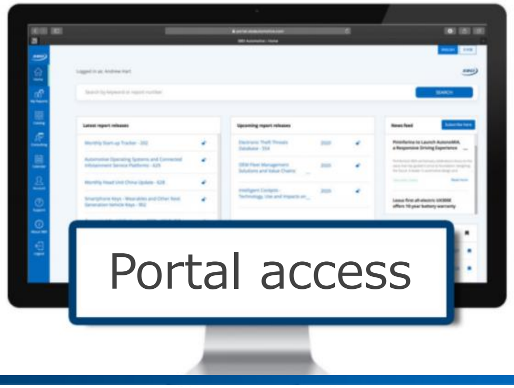

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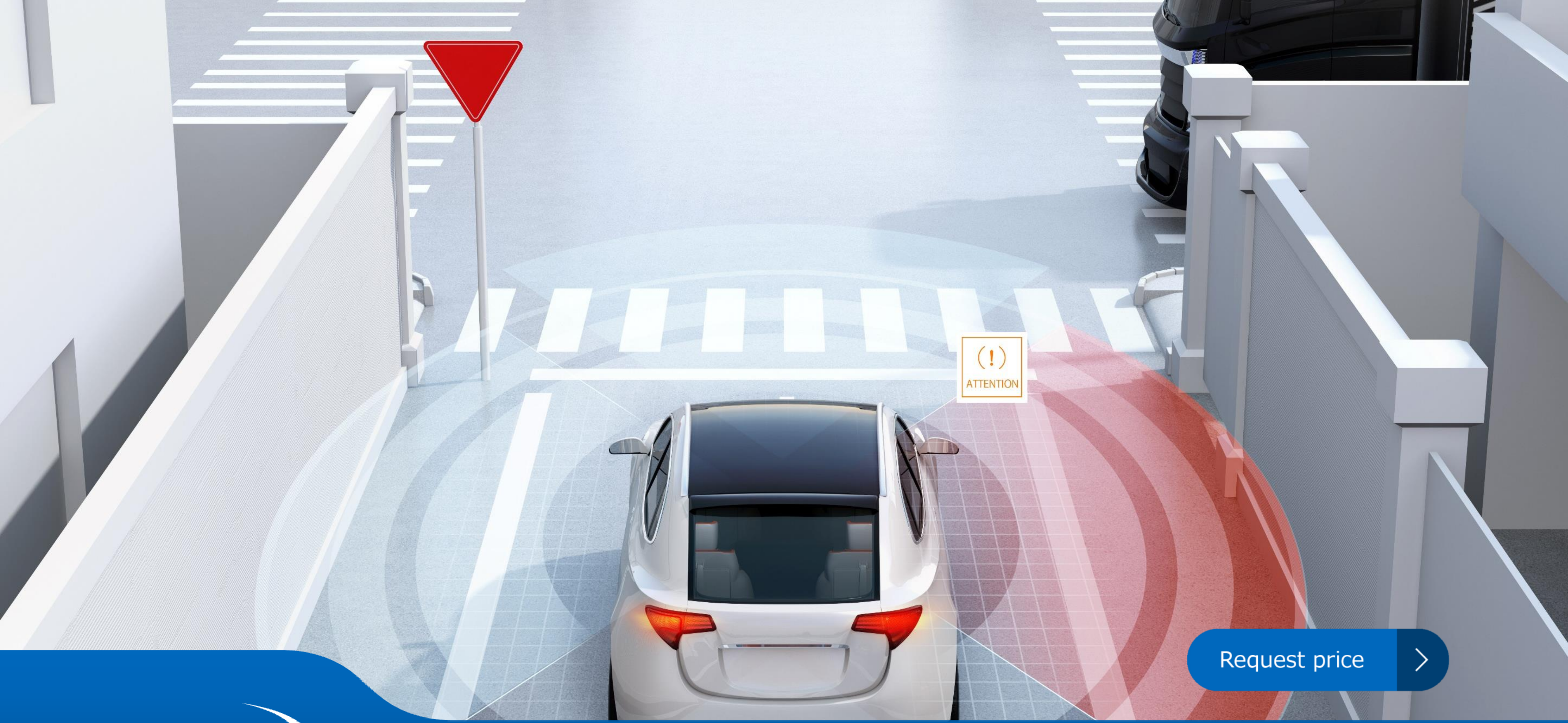

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ADAS SENSOR MARKET LANDSCAPE

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Introduction

Purpose of this report

After more than two decades of active safety development and deployment, the market for advanced driving assistant systems (ADAS) is becoming mature, especially in Europe and in the USA.

Initially, most ADAS were introduced as a one sensor one feature approach, but with increasing systems performance requirements this approach has reached its limitation. Combining the strength of different sensors together is becoming more common. This is particularly true to the more advanced systems available today.

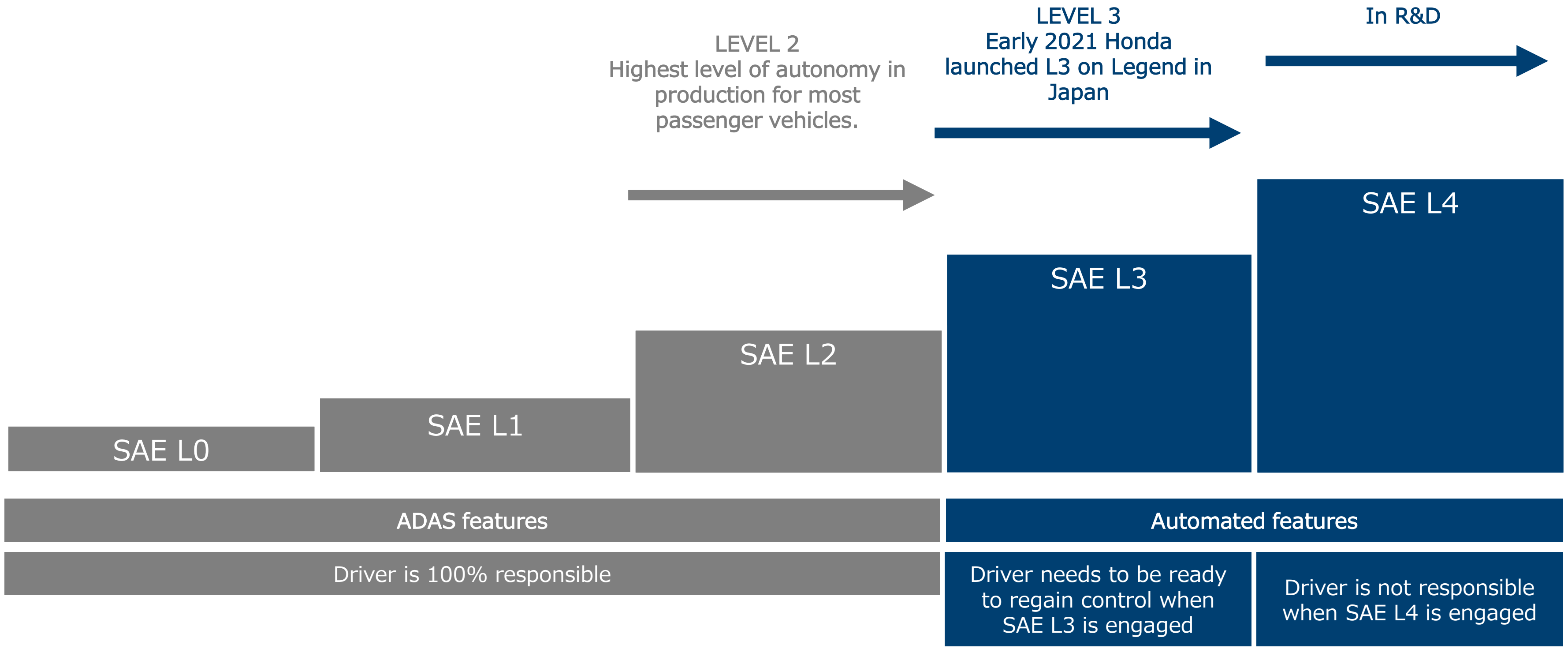
This report provides an overview of the capabilities of each sensor technology (radar, camera, lidar and ultrasonic), identifying various types within each technology, their pros and cons as well as assessing their suitability to support increasing levels of vehicle autonomy. Robustness, detection and classification capability of each sensor type are explained together with OEMs sensor fusion strategies, Tier 1 offering and latest developments. Finally some market forecasts are provided.

This report focusses on the passenger vehicle market in 3 key regions: EU, USA and China. All traditional ADAS are considered in this study. This means that

- Ultrasonic sensors for standard front and rear parking aids are excluded
- Ultrasonic sensors used for automated parking applications are included
- Standalone rear-view camera are excluded
- Rear-view cameras used to support self-parking system or all-around view systems are included

Levels of automation for passenger vehicles

There are different ways of classifying vehicle automation, however the Society of Automotive Engineers (SAE) scale is the most widely approach used in the industry



- The technical and legal challenges associated with the design of SAE L3 and L4 are still very significant. SBD expect the industry to concentrate on SAE L2 and improving their domain of operation for the foreseeable future.
- SAE L3 and L4 will be launched but under very limited conditions in terms of location and environmental conditions.

The last level, SAE L5 corresponds to the automated vehicle that can operate under all possible conditions. With the current state of technology this level cannot be reached in the short to medium term.

Example slides from the 133 page report

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Sensor market is driven by NCAP & homologation requirements

Over the last two decades the different New Car Assessment Programme (NCAP) have been instrumental in improving active safety on new cars.

Significant levels of standardization of collision avoidance systems have been achieved, as most OEMs are aiming to get the top mark when introducing a new vehicle to a market where NCAP is operating.

NCAP

- **Euro-NCAP** – The European organization keep introducing more challenging ratings and still is the most demanding test regime.
- **US-NCAP** has not updated its rating for many years and is significantly behind Euro NCAP in terms of active safety systems. Under the Biden administration it is believed that the rating is more likely to be updated to be more in line with Euro-NCAP, however the timing is yet to be confirmed.
- **C-NCAP** in China has rapidly updated its requirements to get closer to Euro-NCAP rating. It is believed that by 2023 C-NCAP could become even more demanding than its European equivalent.

In Europe, new homologation rules means that many safety systems will soon get mandated.

EU global safety regulations

Global safety regulations have been updated in order to further reduce road fatalities. From 2022 to 2024 several active safety systems will become mandated in Europe, some of which includes:

- emergency braking for pedestrians
- lane keeping
- driver monitoring

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The era of automated vehicles has started

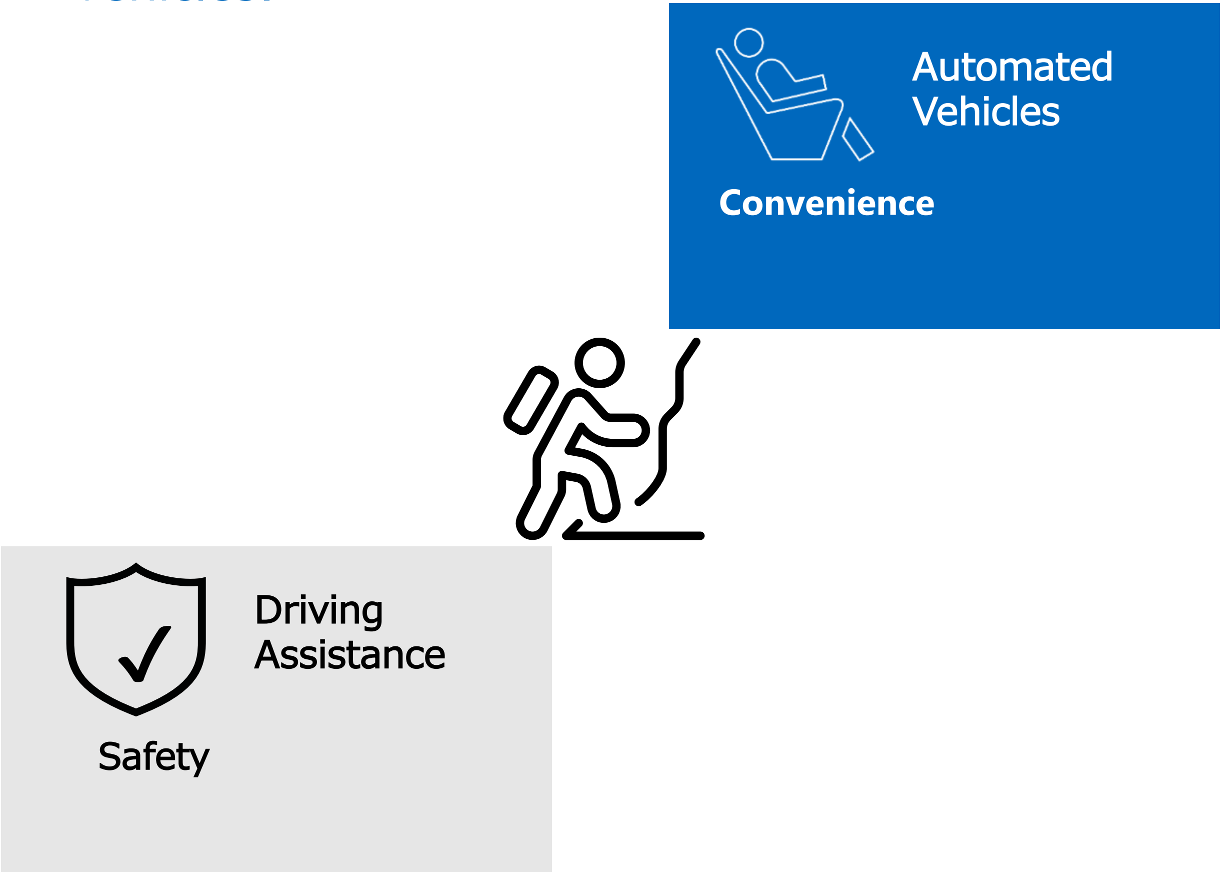
OEMs have introduced an increasing number of ADAS but have not been able to generate a significantly positive business case, in particular for collision avoidance systems, as customers are not willing to pay for extra safety. Associated costs have therefore been absorbed into vehicle base price.

This now gives an opportunity for OEMs to build additional functionality that are not safety focussed but rather try to provide extra convenience. Ideally re-using already fitted ADAS sensors, OEMS have introduced chargeable features aimed at helping the driver manoeuvring in car park (e.g. self parking feature) or reducing the workload on motorways (e.g. hands free driving features). Although the driver is still fully responsible, such systems are building blocks of automated vehicles where the driver is not fully responsible anymore.

With automated vehicles, as the responsibility start to shift away from the “driver”, the robustness requirements are at least one if not two order of magnitude more demanding, thus presenting some significant challenges. In particular more sensor are required so that some redundancy can be implemented. Traditional ADAS sensors need to have their performance improved significantly, as most of them can only perceive the world in 2 dimensions.

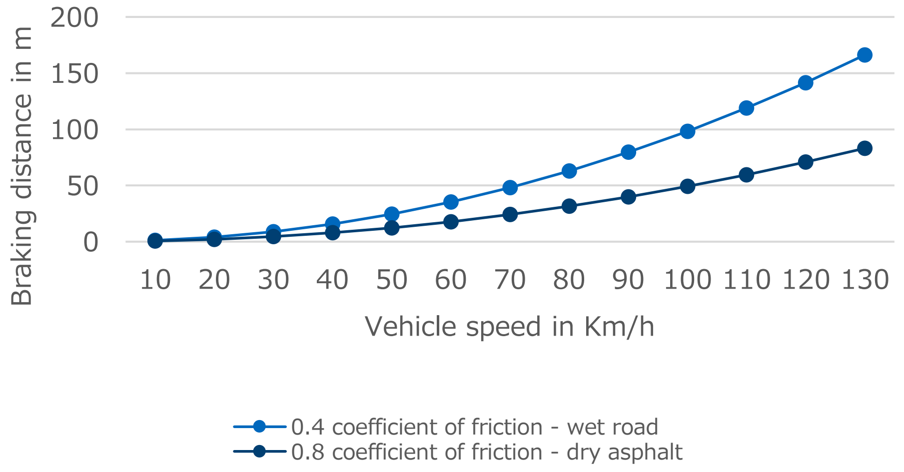
Being able to reliably sense the environment in 3D is one of the many improvements required to unlock the deployment of automated vehicles. So far this has been achieved by having a multitude of sensors (e.g. robot taxi) but this is not applicable to the passenger vehicles for cost and styling reasons.

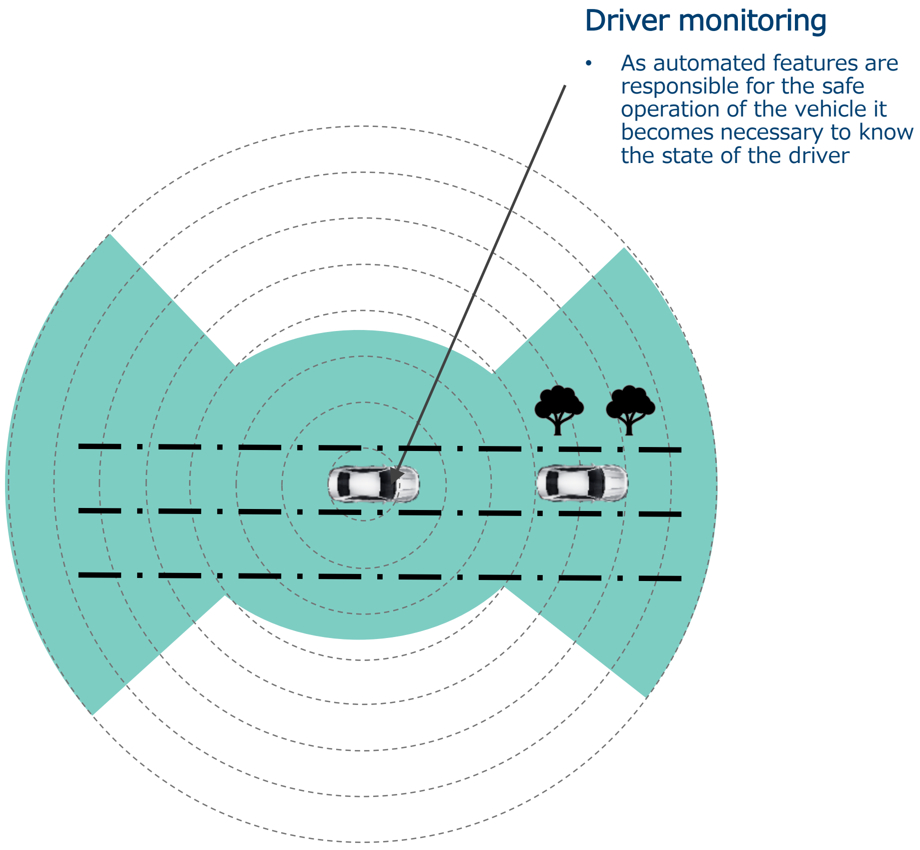
Affordable multimodal 3D perception is key to the deployment of automated passenger vehicles.



Sensing needs for automated features

- To support highly automated systems a single sensing domain becomes necessary. It should ideally provide complete sensing capability around the vehicle, with no blind zones. 360° coverage is necessary to delivery safe and robust automated systems at SAE L3 and above as the vehicle has the responsibility for the driving task when engaged.
- Sensing strategies need to become more robust towards bad weather conditions and poor lighting conditions. This cannot be achieved with just one type of sensor, hence why a mix of sensing modalities is required all around the vehicle (e.g. sensor fusion). The maximum range of the sensor suite also needs to be increased so that a wider range of scenarios can be safely handled.
- The maximum range of the sensor suite is directly linked to the braking distance of the vehicle. When the road coefficient of friction is low (0.4 - wet road) the braking distance is significantly increased, therefore the sensing range needs to match it otherwise a collision cannot be avoided.
- Cabin monitoring is also required to support automated systems as the driving task may be have to transition from the vehicle to the driver in certain circumstances. In order to make this transition safely, the vehicle must assess the drivers physical and cognitive state to ensure that the driver is ready and capable of regaining control.





Single sensing domain

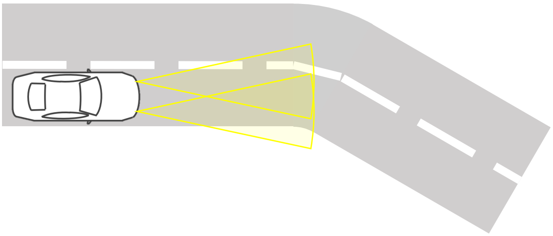
Sensor fusion to improve feature delivery

Sensor fusion can be used for feature optimisation and refinement by overlaying ADAS sensor data with information from on-board sensors and units.

Map data and vehicle's dynamic data are commonly used to provide ADAS feature refinement.

Advanced lighting improvements

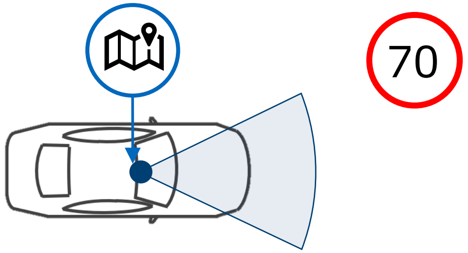
Sensor fusion can enhance the delivery of advanced lighting systems using map data and vehicle's dynamic sensors (e.g. Yaw rate, steering wheel position). By using information about the road curvature ahead, the headlights can be adjusted, and their position optimised to focus on the driving path ahead.



Improve Traffic Sign Recognition system delivery

Traffic Sign Recognition systems use camera sensors to detect and read traffic signs for the driver. However, in certain circumstances the traffic sign may not be able to be read accurately by the system, for example if there is vandalism or another vehicle is blocking the camera from seeing the traffic signs.

To improve the accuracy of the Traffic Sign Recognition system, map data from the navigation system could also be used, which would not be affected by issues affecting the cameras' ability to read the road sign.



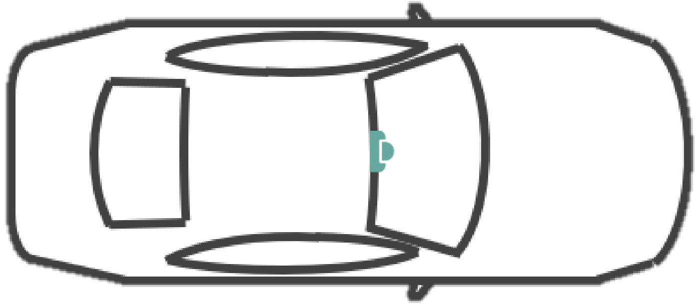
Validate vehicle location before feature activation

Many hands-free systems are designed to work on specific road types to ensure safe operation, typically highway environments with a physical barrier between opposing traffic. Map data can be used to validate that the vehicle is driving on a suitable road before the driver can activate the system. This is especially critical for automated features to validate the suitability of the environment.

Mono camera (visible spectrum) – Front sensing

- Mono camera systems use a single camera to capture images from the environment ahead. The images are then analysed by image processing software to identify and classify objects, which can then be used to support ADAS applications. As mono cameras use a single camera, the systems can only capture and assess a 2D representation of objects and therefore depth information must be determined indirectly.
- Mono vision cameras provide a low cost solution which can support a wide range of features. Advancements in AI and image processing has lead to continual improvements in the detection and classification capabilities of objects.
- Whilst mono camera hardware can be acquired for a low cost, even when compared to other types of camera solution, there is a cost associated with training the systems to provide the required level of performance.
- Mono cameras typically have a range of 100 m (depending on imager size and image processing capability) and a FOV of 45 degrees.

Typical sensor locations



Pros	• Good for object classification • Low cost sensing solution • Easy to package • Low vulnerability to damage as it is typically packages behind the windshield • Suitable for up to high speed applications
Cons	• Passive sensor • Sensitive to weather and lighting conditions • Line of sight sensor • Takes indirect measurements of velocity and distance • Average estimation of width, which is dependent on image processing capability

Features supported	• Collision Avoidance • Adaptive cruise control • Traffic Sign Recognition	• Piloted Driving • Lane Departure Prevention • Auto Headlamp Dipping
Key players	APTIV, BOSCH Invented for life, Continental, DENSO, KOSTAL, MAGNA, Valeo, veoneer, ZF	

Overview of interior sensing

Interior sensing to support ADAS/automated feature is a relatively new topic and is mainly being driven by the need to understand the state of the driver. This is becoming particularly important for automated features (SAE L3 and higher) as for such systems it is necessary to know the state of the driver to safely manage the transition between automated and manual driving.

Some basic driver monitoring (based on steering wheel input) have already been largely deployed, especially in Europe. However, a revision of the EU General Safety Regulation means that from 2022 such systems will become mandated and over time will need to be more capable. The timetable for implementation is given below.

Passenger vehicles , M_1 (8 passenger seats or less)							
		Implementation date					
		New type approvals			All vehicles		
System	Description	2022	2024	2026	2022	2024	2026
E2 Driver drowsiness and attention warning	A system that assesses the driver’s alertness through vehicle systems analysis and warns the driver if needed.	✓				✓	
E3 Advanced driver distraction warning	A system that helps the driver to continue to pay attention to the traffic and that warns the driver when distracted.		✓				✓
E4 Driver availability monitoring system*	A system able to detect driver presence and driver availability status.	✓				✓	

*Required for autonomous vehicle

As with any regulations, the technical solutions are not mandated. It is up to the OEM to decide which technology to use to meet the technical requirements. However, based on the performance requirements it can be deducted that:

E2 system	Regulation can be achieved by monitoring **steering** patterns (wheel reversal rate and /or yaw rate) or variability of the vehicle’s **lateral lane position** from road lane markings. For the latter, the most straight forward solution would be to re-use front cameras already fitted for other features.
E3 system	E3 system: the actual requirements are not available yet (as of September 2021), however the aim of the system is to monitor the driver’s visual attentive state, leaving very little choice in terms of technology solution. Driver monitoring **cameras** are the only credible solution.
E4 system	Part of the **ALKS** regulation (SAE L3 system) which only specifies the need for detecting that the driver is still present and his/her availability to regain control of the vehicle. Such systems are compulsory with SAE L3.

Maps are needed for automated systems

Maps, although not a sensor strictly speaking, are getting increasingly critical to the ADAS/automated sensing stack.

The most recent Piloted driving systems (SAE L2) are for example making extensive use of map data so that the vehicle can for example reduce its speed automatically when approaching a junction or a sharp turn.

Initially, maps developed for turn-by-turn navigation were used, however they lack the required attributes and accuracy as they have designed to provide road level guidance. Such maps are usually referred as standard definition (SD) maps.

The mapping industry has since developed maps dedicated for ADAS/automated features that can support lane level guidance. Such maps are usually referred as High Definition (HD) maps.

The most important aspects of HD maps is their lane model that describes where the lane boundaries are, thus indicating where the vehicle can drive. With ADAS, the lane model is not critical as the driver is always responsible, but this is not the case for automated systems.

Relying only on radars, cameras or lidars for understanding the lane boundaries is not providing the required robustness for SAE L3 and higher. This is because traditional sensors are going to struggle under the following scenarios:

- Sharp curvature: all sensors have a limited FOV. If the road curvature is too severe (e.g. round-about, interchange) the road curvature will be outside of the sensor FOV. The sensing suite will have a very limited capability of understanding the road environment in real-time.
- Poor weather/lighting conditions: All traditional sensors will suffer some range limitations under poor weather or lighting conditions. In some extreme case they could be completely blinded and only HD maps will stay unimpacted.
  Under such scenario the vehicle will need to initiate a minimum risk maneuver (e.g. slowing down, stopping or moving to a layby) and rely on the lane model up until the vehicle is back to a safe state.

> "HD maps will be critical to delivering automated vehicles (SAE L3 and higher)

> "ADAS today are reactive systems rather than predictive due to the limited range capability of their sensors. Maps can be used to help improve this limitation

Sensing technologies by OEM (2/6)

Currently not available	
Announced future offering	○
Currently available	✓

OEM brand	Radar		Camera (front sensing)			Lidar (front sensing)		Notes on current and future offerings
	Front	Rear	Mono	Stereo	Trifocal	Short range	Long range	
Chrysler	✓	✓	✓					Chrysler currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L1.
Citroen	✓	✓	✓			✓		Citroen currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L2.
Dodge	✓	✓	✓					Dodge currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L1.
Dongfeng	✓	✓	✓					Dongfeng currently offer a front radar and mono camera set on their high-end models to support ADAS including their SAE L2 Piloted Driving system.
DS	✓	✓	✓					DS currently offer a typical front radar and mono camera sensor set to support SAE L2 systems such as Piloted.
FAW		✓	✓					FAW currently offer ADAS on a limited number of models. A mono camera sensor to support ADAS up to SAE L2 systems on their high-end models.
Fiat	✓	✓	✓			✓		Fiat currently offer a typical front radar and mono camera sensor set to support SAE L1 systems.
Ford	✓	✓	✓					Ford currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L2 systems.
Geely	✓	✓	✓					Ford currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L2 systems on a range of vehicles.
Genesis	✓	✓	✓				○	Genesis to use a long range lidar to support its first SAE L3 system on the Genesis G90.
GMC	✓	✓	✓					GMC currently offer a typical front radar and mono camera sensor set to support ADAS up to SAE L2 systems.

Aptiv

	Technology	Current Offering	Planned Offering	Recent partnerships/acquisitions*
Radar	24 GHz radar			
	60 GHz radar			
	77 GHz radar	✓		
	79 GHz radar			
Camera	Mono camera	✓		
	Stereo camera			
	Trifocal camera			
	Near infrared camera			
	Far infrared camera			
	Driver monitoring camera	✓		
	Surround view camera			
Lidar	Long range lidar			
	Short range lidar			
Ultrasonic	Ultrasonic sensors			

Supplier overview

Aptiv is a tier-1 electronics and powertrain component supplier. Aptiv's ADAS sensor portfolio is a selective offering of radar, V2X module and camera units. The company announced it's next generation ADAS platform in 2021, which will be capable of SAE Levels 1-3 autonomy.

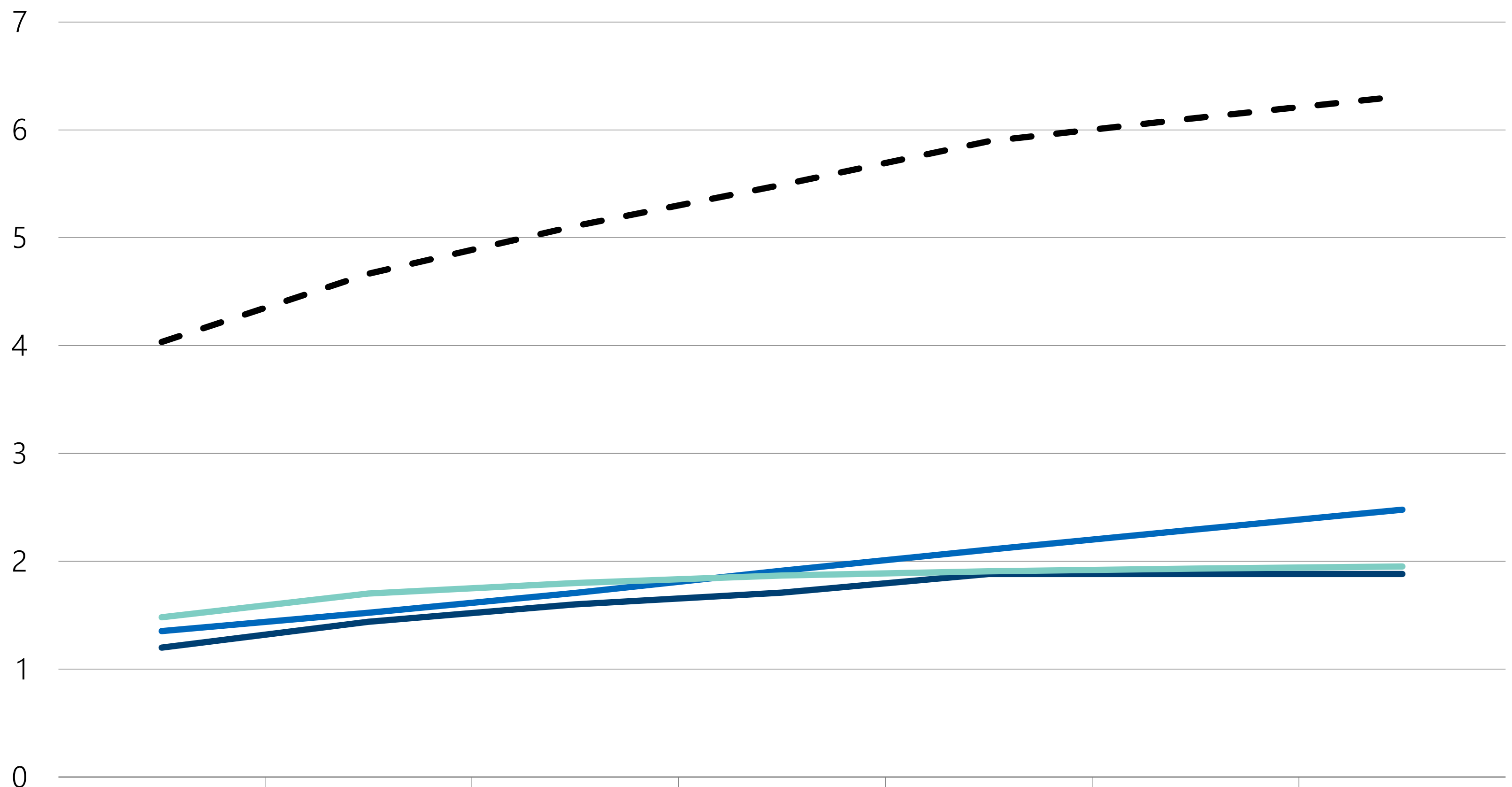
Aptiv has been active in the development and deployment of autonomous systems. To achieve this the company has made a wide range of investments, partnerships and acquisitions to bolster their sensor offerings to support current ADAS systems as well as to deliver autonomous mobility services of the future. For example, Aptiv partnered with Audi to produce the zFAS, one of the first dedicated driver assistance domain controller boards, which is part of the latest Audi A8, capable of SAE L3 autonomy.

Aptiv has been active in the autonomous mobility space and have formed the following key partnerships:

- Partnered with Lyft in 2018 to launch a fleet of 30 autonomous vehicles on their ride-sharing network. The fleet completed 100,00 paid rides in Las Vegas.
- Formed the joint-venture Motional with Hyundai in 2020; a $4 billion investment to develop autonomous driving technology. Motional aims to have a production-ready autonomous platform available for OEMs, taxi providers and fleet operators by 2022.
- Acquired nuTonomy in 2017 to accelerate its commercialization of automated driving and autonomous mobility on-demand solutions.

*Recent partnerships include those from 2019 until present

77 GHz radar – Tier 1 market value (billion USD)



	2020	2021	2022	2023	2024	2025	2026
China	$1,352,132,570	$1,523,359,656	$1,708,298,696	$1,913,808,496	$2,107,177,416	$2,294,528,000	$2,478,956,958
Europe	$1,199,496,710	$1,440,414,192	$1,601,801,562	$1,708,601,364	$1,881,181,746	$1,882,213,440	$1,883,215,430
USA	$1,480,497,020	$1,700,778,744	$1,799,855,000	$1,867,516,872	$1,906,409,682	$1,931,570,720	$1,950,924,276
Total	$4,032,126,300	$4,664,552,592	$5,109,955,258	$5,489,926,732	$5,894,768,844	$6,108,312,160	$6,313,096,664

- The total market for 77 GHz radar is expected to increase from $4.1 billion to $6.3 billion by 2026.
- The USA is currently the largest market for 77 GHz radar sales of the regions considered. However, SBD believes that China will become the largest market by 2026 with a revenue of $2.48 billion.
- 77 GHz radar sales in Europe will largely be driven by the European Commission mandate which will ensure that every car will be sold with a Collision Avoidance system by 2022 on new platforms and on all new vehicles sold from 2024.
- In the USA, 20 OEMs have signed a Memorandum of Understanding to offer Collision Avoidance systems as a standard features on all of their new cars sold from August 2023; this will significantly increase radar deployment in the USA market.

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