UK Automotive Perception Sensors Landscape and Recommendations

Report

06/08/2025

Version 1.1

Authors
Edlyn Dcruz, AESIN, edlyn.dcruz@techworks.org.uk
Gunny Dhadyalla, AESIN, gunny.dhadyalla@techworks.org.uk

With contributions from the Sim4CAMSens consortium

Executive Summary

This report has been prepared as part of the Innovate UK funded Sim4CAMSens project.

It provides a comprehensive overview of the UK's current capabilities, challenges, and opportunities in the field of automotive perception sensors, which are critical for enabling Advanced Driver-Assistance Systems (ADAS) and Connected and Automated Mobility (CAM) technologies.

Market Context and Strategic Importance: The global automotive sensor market is projected to grow from $30.8B in 2023 to $62.2B by 2028. The UK ADAS market is expected to reach $3.2B by 2033, with CAM technologies potentially contributing £66B annually by 2040 and creating 38,000 jobs. The UK has strong academic and industrial foundations in radar, photonics, and quantum technologies, but lacks Tier 1 automotive sensor manufacturers.

Technology Assessment: Radar technology is identified as the UK's strongest growth area due to historical expertise and active R&D. High potential for IP development and industrialisation**.** **Camera systems** are a mature technology with UK strengths in image processing and AI. Some growth potential through academic spinouts and IP development. **LiDAR sensors** offer limited UK manufacturing presence but strong academic research. Growth potential hinges on investment and international collaboration. **GNSS & IMU**: Mature technologies with some UK suppliers. Opportunities exist in cross-sector innovation and quantum-enabled PNT. **Onboard Compute** presents the UK with limited presence but strong quantum computing R&D in an industry dominated by global players (e.g., NVIDIA).

Key Challenges for the UK include High development costs and lack of domestic manufacturing, the absence of Tier 1 suppliers headquartered in the UK, and regulatory gaps despite the 2024 Automated Vehicles Act.

Recommendations from the report:

- **Boost R&D Funding:** Especially for SMEs and startups in sensor innovation.
- **Support Commercialisation:** Scale-up funding and VC engagement to help UK firms bring products to market.
- **Develop Domestic Capabilities:** Incentivise local design and production and build strategic international partnerships.
- **Invest in Advanced Technologies:** Focus on solid-state LiDAR, AI-enhanced radar, and quantum-enabled PNT.

Contents

1 Introduction

Perception sensors are integral to the advancement of automated vehicles (AVs), enabling these systems to accurately perceive and interpret their environment. In the UK, these sensors are essential not only for unlocking the full potential of self-driving technologies but also for improving road safety through the implementation of advanced driver-assistance systems (ADAS). Despite significant progress in the development of perception sensor technology, several challenges persist, including regulatory gaps, high development costs, and the lack of a UK-based sensor supply chain. This report offers a comprehensive analysis of the current landscape of automotive perception sensors in the UK and outlines key recommendations to address these challenges and promote growth in the sector.

2 Current Landscape of Automotive Perception Sensors in the UK

2.1 Market Overview

The automotive perception sensor market is growing rapidly, driven by the increasing demand for ADAS and the development of automated driving technologies. Notable market projections include:

- The global automotive sensors market was valued at $30.8 billion in 2023, with an expected growth to $62.2 billion by 2028, achieving a compound annual growth rate (CAGR) of 15.0% during the forecast period [1].
- The UK ADAS market is projected to reach USD 3,232.9 million by 2033, growing at a CAGR of 11.13% from 2023 to 2033 [2].
- The 2024 Shoosmiths and KPMG report "Unlocking the UK CAM Opportunity "projected an Estimated annual economic benefit of £66 billion: to the UK by 2040 from widescale adoption of Connected and Automated Mobility (CAM) technologies[3].

2.2 Key Developments and Initiatives

The UK government has demonstrated a strong commitment to advancing automated vehicle technologies, including the integration of perception sensors in automotive applications:

- In February 2023, the UK government allocated £81 million in grants to support the commercial use of self-driving vehicles, including automated buses, taxis, and shuttle services, set to commence in 2025[4].
- The Automated Vehicles Act 2024 received Royal Assent in May 2024, providing a legal framework to regulate AV testing and deployment in the UK[5].
- The **Commercialising Connected and Automated Mobility (CAM) Supply Chain** programme is a UK government initiative led by the Centre for Connected and Automated Vehicles (CCAV), in partnership with Innovate UK and Zenzic. It supports 13 projects involving 43 companies with over £28.5 million in funding to strengthen the UK's self-driving vehicle supply chain[6].

2.3 Sensor Technologies Outlook

This section delves into the UK strengths and opportunities for sensor and sensor related technologies. Historically, the UK is known for its strength in radar technology. Radar was invented in the UK, and the UK has a strong cross-sector radar development community, which could be attracted more strategically into the automotive industry. The UK has also had a strong university presence undertaking research in photonics, which could be spun out into supply chain. One example is the £21.9m Quantum Enabled PNT programme awarded to University of Glasgow building on their excellence in both photonics and security.

In Table 11, we summarise the outcomes of the analysis carried out for the different perception sensors and related technologies, followed by a detailed review of each of the technologies.

Table 11. Technology maturity and UK potential for growth

Technology	Current Maturity	UK Potential for Growth
Camera		
Radar		
Lidar		
GNSS and IMU		
Onboard Compute (sensor data fusion)		

Key: High | Some | Low

2.3.1 Camera

Typical Functions

- Surround vision
- Object detection and recognition
- In-vehicle driver and occupant monitoring

Types

- Visible, near infrared (NIR), time of flight (ToF).
- Monocular vision, stereo vision, spatially distributed for surround vision.
- Raw camera data or with internal image processing to provide information.

Current and Future Outlook

Technology is in a mature state in the automotive market driven by Advanced Driver-Assistance Systems (ADAS) and advances from consumer electronics, with several suppliers across the supply chain. Visible spectrum cameras with internal image data processing are commonplace for on-road vehicles to enable functions such as line detection, object detection, and traffic-sign recognition.

It is expected that there will be continued performance improvements in Image Signal Processing (ISP), e.g. higher resolution, and more efficient data compression. Event based cameras[7] also known as neuromorphic cameras, are an emerging camera type that can reduce data transmission bandwidth and latency, which may find applications in Automated Vehicles (AVs). Wavelengths other than in the visible spectrum are less common on vehicles (e.g. NIR cameras can be found on high-end vehicles for night vision) and are typically much more costly. But these may become more widely adopted in the future.

Current Maturity: High

UK and International Capabilities

There are some UK Tier 2 and Tier 3 suppliers developing cameras, with high-value skills present in the UK for R&D and design. There are several notable academic institutions and industry partners working on developing novel concepts which could be leveraged by industry.

Key UK contributions:

- Data processing on camera (U. Manchester[8], U. Bristol, On-Semi)
- Object detection and classification using AI (U. Warwick, U. Manchester, U. Bristol, *U. Limerick, Valeo*)
- Data compression (U. Warwick[9], On-Semi)
- Image Signal Processing (U. Loughborough[10])

At present there is no significant manufacturing in the UK. The leading suppliers of camera technologies are in Japan (Sony, Denso, Panasonic), South Korea (Samsung, LG Innotek), Germany (Continental, Bosch, ZF), and North America (NA) (TRW, FLIR, OmniVision Technologies).

Current UK Potential for Growth: Medium

There is potential to expand the development of camera sensor design IP, leveraging existing knowledge and expertise in the UK. There is also the opportunity for spin outs from universities given the high-quality research outputs.

The UK has well-established technologies in Tier 2 and Tier 3, particularly for visible spectrum cameras, with a possibility to grow. It should be attractive for inward investment on sensor design, e.g. System on Chip (SoC) and signal processing, as well as continued development and iterative improvements in performance, e.g. better object detection, and more efficient data compression methods. Emerging camera types, such as event-based cameras, have the potential to disrupt the market and should be considered.

2.3.2 Radar

Typical Functions

- Adaptive Cruise Control (ACC) (object detection and velocity)
- Automatic Emergency Braking (AEB)
- Blind spot detection and clear exit detection

Types

- Two main types: pulsed-Doppler and frequency modulated continuous wave.
- Often tuned for short, medium, and long-range operation.
- Typical operating frequency 77GHz and 24GHz.

Current and Future Outlook

Radar is a maturer technology with several well-established Tier 1 automotive suppliers in the EU. Sensors are often integrated on a vehicle in forward-facing and corners/sides positions to support ADAS features, such as ACC, blind spot detection, and clear exit detection[11].

In recent years, there have been significant developments in 4D-imaging radars that can provide point clouds[12]. These are becoming very attractive to AV developers given that 4D radars are typically lower cost than Light Detection and Ranging (LiDAR), albeit offering a much less dense point cloud. In addition, given the lower cost per unit, there is an opportunity to design multiple radars positioned around the vehicle to achieve surround 'vision' for AV applications.

Terahertz frequency, e.g. 150GHz and 300GHz radars are currently being studied by several research groups in the UK[13]. The shorter wavelength can offer higher resolution, and is able to use wider bandwidths, which can improve range resolution. At present, these frequencies are not certified for road use, but this is likely to change if significant benefits can be realised.

Current Maturity: Medium

Note, this maturity refers to 4D radar, while existing radar used in ACC has a high maturity.

UK and International Capabilities

The UK has a long and distinguished history in radar technology[14]. Similarly, the UK is a significant player in antenna design across many domains. There are several suppliers developing radar technologies in the UK, however, only some develop specifically for automotive with many more developers for defence and aerospace applications. Costs and specs for non-automotive applications are generally too high for automotive.

Key UK contributions:

- Imaging radar and algorithm development (OxfordRF[15], U. Birmingham[16], AptCore[17], RADAREYE[18])
- High-resolution scanning radar[19] (Navtech)
- Doppler[20] (Kestrel, U. Birmingham)
- Ground penetrating radar (Utsi Electronics[21])
- Radar SoC (Infineon[22])
- Aerospace, naval, deep space (BAE Systems, Leonardo, Qinetiq, Elbit)

The majority of automotive radar suppliers are in the EU and RoW. Leading suppliers reside in Germany (Continental, Bosch, ZF, SmartMicro).

Current UK Potential for Growth: High

There is high potential to expand the development of current and future generation of radar sensor design IP and algorithm development, leveraging existing knowledge and expertise in the UK.

The UK's distinguished history of radar technology leadership from sectors such as aerospace and maritime, and the pockets of leading automotive radar research in both academia and industry, offer opportunities to grow these capabilities. However, there are notable gaps in the product supply chain. Radar should be attractive for more inward investment on design. Radar manufacturing scale-up in the UK will depend on the market demand for next generation designs that challenge current leading suppliers.

2.3.3 LiDAR

Typical Functions

- Object detection and ranging
- Localisation and mapping
- ACC

Types

- Rotating laser beam with mechanical positioning, typically via a Microelectromechanical System (MEMS)-based mirror.
- Solid-state with no moving parts within the sensor.
- Pulsed LiDAR using time of flight information.
- Continuous wave LiDAR using frequency or amplitude information[23].

Current and Future Outlook

LiDAR technology is rapidly advancing and becoming increasingly important for the automotive industry. As an active sensor that interrogates the environment it is often paired with passive sensors, such as cameras, to create a more robust perception sensor suite. Widespread adoption of LiDAR has yet to happen in production vehicles given the high costs of sensors. Some premium Original Equipment Manufacturers (OEMs), e.g. Audi[24] and Volvo[25] have started integrating simpler LiDARs into vehicles to support ADAS features such as ACC, lane keeping assist (LKA), and AEB. That technology is likely to trickle down to other model ranges. Similarly, LiDAR is featured on most AV platforms in development, particularly those for the leading early commercialisation applications.

The outlook for LiDAR is promising, with continued growth expected in the coming years driven by the increasing demand for higher levels of vehicle autonomy and the need for enhanced safety features. With increasing competition and the emergence of alternative lower-cost sensor technologies, such as imaging RADAR, unit prices for LiDAR are expected to continue to fall. Further new LiDAR types with different operating techniques and characteristics, such as longer wavelengths, continue to be explored and be developed[26].

Current Maturity: Medium

UK and International Capabilities

There is no LiDAR hardware manufacturing presence of note for automotive in the UK. There is strong R&D, particularly in universities:

Key UK contributions:

- Surveying (U. Edinburgh[27], U. Hertfordshire[28])
- Sensor noise modelling (U. Warwick[29], NPL)
- SoC and light sources design (U. Southampton[30], U. Aston[31], U. Glasgow[32], Vector Photonics[33], CSA-Catapult[34], Custom Interconnect[35] Ltd, Phlux Technologies[36])

The UK does have some LiDAR products serving other markets, e.g. ZX Lidars[37] for wind measurement. Most automotive LiDAR suppliers are in NA (Velodyne, Ouster, Luminar, Seyond), Asia (Hesai, RoboSense, Livox, Innoviz), and EU (Valeo, Ibeo, Continental).

Current UK Potential for Growth: Limited

Building from a strong academic base at low TRL research, and some cross-sector presence at higher TRL in non-automotive applications, gives some limited potential to increase LiDAR sensor design IP and algorithm development in the UK. However, this may be difficult to pull through into higher TRL without significant investment, facilities, and industrial companies prepared to sustain the risk. There is also some potential for spinouts from the leading universities if investments are made for the long term.

Most LiDAR sensor suppliers are in NA and Asia. Overall, it is a very competitive global landscape, which makes it particularly difficult for inward investment. International collaboration with the world leading photonics groups could be encouraged as an alternative to develop novel and next generation sensor types.

2.3.4 GNSS and IMU

Typical Functions

- Provides positioning (global reference), speed and orientation of the vehicle
- Dead reckoning and navigation
- Vehicle dynamics control for suspension, roll over prevention

Types

- Global Navigation Satellite System (GNSS) with the support of specific satellite constellations, e.g. NA's Global Positioning System (GPS), Russia's Global Navigation Sputnik System (GLONASS), Europe's Galileo, and China's BeiDou[38].
- GNSS with additional corrections for further precision, e.g. using Real-time Kinematic (RTK), Precise Point Positioning (PPP)[39].
- Inertial Measurement Unit (IMU) with silicon MEMS (most common in automotive), or fibre optic gyro, or ring laser gyro[40].

Current and Future Outlook

In general, GNSS and IMU technologies are very mature as they have had decades of development and widespread use in applications such as surveying, navigation, and tracking. Most modern vehicles have a GNSS receiver and IMU to support navigation[41], connected car applications (e.g. tracking) and vehicle dynamics tuning. These sensors are typically low cost with low performance, which is generally not suitable for automated driving functions.

It is expected that ongoing research and development will continue to improve accuracy, reliability and robustness of these sensor types. Costs are also expected to continue to reduce over the coming years. Other key areas of development include multi-frequency and multi-constellation GNSS devices in smaller packages, high precision IMUs, more advances sensor fusion algorithms, and more robust anti-spoofing and anti-jamming techniques.

The emergence of quantum technologies for more resilient Position, Navigation and Timing (PNT)[42] could trigger a step change in performance and security. The University of Glasgow is leading the £21.9 million over the next five years to develop smaller, lighter quantum-enabled devices for new applications in sectors including roads, railways and underground transport. The programme has established an Independent Advisory Board (IAB) to ensure technology transfer to industry and to be alert to commercialisation potential for UK industry.

Current Maturity: High

UK and International Capabilities

There are a handful of developers and suppliers in the UK.

Key UK contributions:

- SoC and complete GNSS solutions (OXTS[43], VBOX Automotive[44], Zeropointmotion[45])
- IMU (VBOX Automotive[44], x-io Technologies[46])
- Military and aerospace PNT applications (BAE Systems, Collins Aerospace[47])

Most leading suppliers are based in the EU (Septentrio, u-blox, Leica, SBG Systems), NA (Novatel, Trimble, Hemisphere) and China (CSNS).

Current UK Potential for Growth: Medium

The UK has some limited presence in developing complete GNSS solutions and IMUs. There are examples of complete high-end GNSS solutions to support testing purposes during development, which will benefit from more potential fundamental research, but high-volume products for passenger car applications are not envisaged. There is potential to attract cross-sector entry into CAM when paired with emerging new technologies, such as quantum, where the UK is a significant contributor.

3 Challenges in UK Automotive Perception Sensors

3.1 High Development and Deployment Costs

Although perception sensors such as LiDAR are essential for AV functionality, they remain prohibitively expensive, which can limit their adoption, particularly by small and medium-sized enterprises (SMEs). Additionally, the lack of domestic manufacturing capabilities in the UK means that a significant portion of these sensors are imported from foreign suppliers, primarily from the US and China, further driving up costs. These high costs are a major barrier to the rapid commercialisation of AV technologies [48].

3.2 Lack of Established Higher-tier Supplier

The UK does not have a Tier 1 electronics and software systems supplier headquartered here. Most of the Tier 1 supplier presence is through technical support, sales and business development. For the UK to be truly competitive there needs to be mechanisms in place that either enable the excellent research outcomes to be spun out into the next generation of companies or develop sufficient demand to attract inward investments from international technology developers. This can only be done through more attractive R&D programmes, where there is genuine intention to grow UK capability.

3.3 Regulatory Framework

The regulatory environment for automotive perception sensors in the UK still requires comprehensive updates to facilitate AV technology deployment. The Automated Vehicles Act 2024[49] provides a foundation, but further detailed translation to the technology, including sensors, is needed specifically in reference to the need for a Statement of Safety Principles as well as the Act's empowerment to set technical standards for compliance.

4 Recommendations

Based on the challenges identified in Section 3, this section proposes recommendations for supporting the UK's perception sensors industry.

4.1 Support Research and Development

- **Increase Funding:** The government should increase R&D funding for startups and SMEs working on next-generation perception sensor technologies, particularly those focused on miniaturisation, lower costs, and greater accuracy. This will help to reduce the financial barrier to the widespread adoption of these technologies.
- **Promote Public-Private Partnerships:** Encouraging collaboration between the government, universities, and industry will facilitate breakthroughs in sensor technology, including cost-effective alternatives like AI-enhanced radar systems, quantum enabled PNT, solid-state LiDAR and. Public-private partnerships can help mitigate the high costs associated with sensor development.

4.2 Commercialisation / Route to market

- **Go to Market/Scale up Funding:** Most of the UK organisations developing new sensors are SMEs or startups without the commercial presence to bring their technologies / products to market. The UK needs to derisk the scale up of new technologies through directed funding.
- **Private Funding:** Scaling technology businesses in the UK requires more than innovation—it needs significant investment. While early-stage startups may rely on grants, scaling demands **private, venture capital (VC), or equity funding** to support growth, market expansion, and infrastructure. The UK has a strong VC ecosystem, with billions invested annually in sectors like AI and fintech. These investors not only provide capital but also strategic support. To maintain global competitiveness, the UK must ensure a steady flow of private and institutional funding to fuel its tech scale-ups in the perception sensor space.

4.3 Develop Domestic R&D and Manufacturing Capabilities

- **Strategic Trade Partnerships:** The supply chain for complex technologies is global meaning that design, development, testing and manufacturing occurs across multiple boarders for any given system. The UK is in a position where it needs to develop and grow strong international partnerships to leverage skills and manufacturing economies. This means business models where design and IP generation is retained, the manufacturing and testing is with trusted partners, and the subsequent sale of products and services are controlled by the UK operations.
- **Incentivise Local Production:** Where possible and guided by UK Technology expert direction, the UK government should incentivise the domestic manufacturing of

automotive perception sensors or their subcomponent assemblies. This will strengthen the local supply chain and contribute to the UK's competitiveness in the global automotive sector [8].

- **Invest in Advanced Technologies:** The government should support research into cost-effective, advanced sensor technologies, such as solid-state LiDAR, AI-enhanced imaging radar, imaging ultrasonics and integrated sensors to improve the competitiveness of the UK's sensor industry [8].

5 Conclusion

Based on publicly available data and interviews with subject matter experts, revealed radar as a **high** potential technology for growth in the UK. However, strong international competition is a challenge that requires support in terms of R&D funds, talent development, outward international engagement, and supplier/procurement development. Furthermore, limited manufacturing capability is a further challenge that requires support in terms of industrialisation and low volume manufacturing facilities.

The UK has a long and distinguished history in RADAR technology. Similarly, the UK is a significant player in antenna design across many domains. There are several suppliers developing RADAR technologies in the UK, however, only some develop specifically for automotive with many more developers for defence and aerospace applications. This is because costs and specifications for non-automotive applications are generally too high for automotive.

Vision systems are mature, however opportunities in data processing and fusions may exist and are fertile territories for academic research.

The UK's strength in photonics also provides opportunities for quantum enabled solutions for example position, navigation and timing. Although Lidar is seen as a low potential technology, there are still significant opportunities for the UK's photonics industry should it pivot. Addressing the challenges related to cost and performance which are the biggest barriers for widespread adoption.

Glossary

Term	Definition
ACC	Adaptive Cruise Control – a system that automatically adjusts vehicle speed to maintain a safe distance from vehicles ahead.
ADAS	Advanced Driver-Assistance Systems – technologies that enhance vehicle safety and driving experience.
ADS	Automated Driving System – the hardware and software that enable AV functionality.
AI	Artificial Intelligence – simulation of human intelligence in machines for tasks like perception and decision-making.
AV	Automated Vehicle – a vehicle capable of sensing its environment and operating without human input.
CAM	Connected and Automated Mobility – integration of connectivity and automation in transport systems.
CAPEX	Capital Expenditure – funds used by an organisation to acquire or upgrade physical assets.
CCAV	Centre for Connected and Autonomous Vehicles – UK government body supporting CAM development.
CAGR	Compound Annual Growth Rate – a measure of growth over multiple time periods.
DSP	Digital Signal Processing – manipulation of signals to improve performance or extract information.
FPGA	Field Programmable Gate Array – an integrated circuit that can be configured after manufacturing.
GNSS	Global Navigation Satellite System – satellite systems providing geolocation and time information.
GPS	Global Positioning System – a GNSS operated by the United States.
GLONASS	Global Navigation Satellite System – Russia's GNSS.
GPU	Graphics Processing Unit – a specialised processor for rendering images and accelerating AI tasks.
HPC	High Performance Computing – computing systems with high processing power for complex tasks.
IMU	Inertial Measurement Unit – a device that measures acceleration, orientation, and angular velocity.
IP	Intellectual Property – creations of the mind such as inventions, designs, and symbols.
ISP	Image Signal Processing – techniques used to enhance and interpret image data.
LiDAR	Light Detection and Ranging – a remote sensing method using laser light to measure distances.
MEMS	Microelectromechanical Systems – miniaturised mechanical and electro-mechanical elements.

OEM	Original Equipment Manufacturer – a company that produces parts or equipment that may be marketed by another manufacturer.
PNT	Position, Navigation, and Timing – technologies that provide spatial and temporal data.
PPP	Precise Point Positioning – GNSS correction technique for high-accuracy positioning.
RADAR	Radio Detection And Ranging
RTK	Real-Time Kinematic – GNSS technique that enhances positioning accuracy using base station corrections.
SME	Small and Medium-sized Enterprise – businesses with limited scale in terms of employees and revenue.
SoC	System on Chip – an integrated circuit that consolidates all components of a computer or electronic system.
TRL	Technology Readiness Level – a scale to assess the maturity of a technology.
VC	Venture Capital – funding provided to startups and small businesses with high growth potential.

References

[1] **MarketsandMarkets. (2023).** *Automotive sensors market*. MarketsandMarkets. Retrieved from https://www.marketsandmarkets.com/Market-Reports/automotive-sensors-market-426.html?

[2] **Spherical Insights. (2023).** *United Kingdom advanced driver assistance systems market*. Spherical Insights. Retrieved from https://www.sphericalinsights.com/reports/united-kingdom-advanced-driver-assistance-systems-market

[3] **Shoosmiths LLP. (2024, September 3)**. *Unlocking the UK CAM opportunity*. Shoosmiths. https://www.shoosmiths.com/insights/articles/unlocking-the-uk-cam-opportunity

[4] **UK Government. (2023).** *Self-driving vehicle trials funding*. UK Government. Retrieved from https://www.publictechnology.net/2023/12/01/transport/government-backs-self-driving-cars-with-150m-funding/

[5] **UK Parliament. (2024).** *Automated Vehicles Act 2024*. UK Parliament. Retrieved from https://www.legislation.gov.uk/ukpga/2024/10/contents

[6] **Innovate UK (2022)** *Commercialising Connected and Automated Mobility: Supply Chain*. [online] Available at: https://apply-for-innovation-funding.service.gov.uk/competition/1350/overview/be7d536d-553c-445f-a0da-f9ed423469dd [Accessed 10 Jul. 2025].

[7] Gehrig, D., & Scaramuzza, D. (2024). *Low-latency automotive vision with event cameras*. **Nature, 629**(8014), 1034–1040. https://doi.org/10.1038/s41586-024-07409-w

[8] University of Manchester. (2020, October 15). *Cameras that can learn*. https://www.manchester.ac.uk/about/news/cameras-that-can-learn

[9] **Chan, P. H., Wei, C., Huggett, A., & Donzella, V. (2025).** Raw camera data object detectors: An optimisation for automotive video processing and transmission. *IEEE Access, 13*, 21695–21706. https://ieeexplore.ieee.org/document/10839399

[10] **Loughborough University.** (n.d.). Digital cameras. Retrieved July 10, 2025, from https://www.lboro.ac.uk/research/spotlights/digital-cameras/

[11] **Caradas. (n.d.).** *Front radar sensors and their role in ADAS systems*. Retrieved July 10, 2025, from https://caradas.com/front-radar-sensors/

[12] **Aptiv. (n.d.).** *What is 4D imaging radar?* Retrieved July 10, 2025, from https://www.aptiv.com/en/insights/article/what-is-4d-imaging-radar

[13] **University of Birmingham**. (n.d.). *Terahertz electronics.* Retrieved July 10, 2025, from https://www.birmingham.ac.uk/research/activity/eese/terahertz-electronics

[14] **Imperial War Museums. (n.d.).** *How radar gave Britain the edge in the Battle of Britain*. Retrieved July 10, 2025, from https://www.iwm.org.uk/history/how-radar-gave-britain-the-edge-in-the-battle-of-britain

[15] **Oxford RF. (n.d.).** *Our products*. https://www.oxrf.co.uk/our-products/

[16] **University of Birmingham. (n.d.).** *Microwave Integrated Systems Laboratory (MISL)*. https://www.birmingham.ac.uk/research/activity/eese/communications-sensing/misl

[17] **AptCore. (n.d.).** *ACR10X – DSP core for radar processing*. https://aptcore.com/products/acr10x/

[18] **RadarEye. (n.d.).** *Cross-modal radar-camera AI solutions*. https://radareye.ai/

[19] **Navtech Radar. (n.d.).** *Safety is everything*. https://navtechradar.com/

[20] **Kestrel Radar Sensors. (n.d.).** *Radar detection solutions and speed signs*. https://kestrelradarsensors.com/

[21] **PipeHawk. (n.d.).** *Ground penetrating radar and subsurface detection solutions*. https://pipehawk.uk/

[22] **Infineon Technologies. (n.d.).** *Radar sensors*. https://www.infineon.com/cms/en/product/sensor/radar-sensors/

[23] **Think Autonomous. (n.d.).** *Types of LiDAR: A hardcore look at 9 types of LiDAR systems*. https://www.thinkautonomous.ai/blog/types-of-lidar/

[24] **Hawkins, A. J. (2017, July 11).** *Audi's new A8 is the first production car to offer Level 3 autonomy*. The Verge. https://www.theverge.com/2017/7/11/15952510/audi-a8-level-3-autonomous-driving-self-parking

[25] **Luminar Technologies. (2022, November 9).** *The new, all-electric Volvo EX90 with Luminar Technology*. https://www.luminartech.com/updates/ex90

[26] **White, B. (2024, July 8).** *What's the direction for automotive LiDAR: 905 nm or 1550 nm?* EE Times. https://www.eetimes.com/whats-the-direction-for-automotive-lidar-905-nm-or-1550-nm/

[27] **University of Edinburgh. (n.d.).** *Application areas.* https://airborne.ed.ac.uk/airborne-research/application-areas

[28] **University of Hertfordshire. (n.d.).** *Improving air quality through LIDAR*. https://www.herts.ac.uk/research/impact-our-research/case-studies/improving-air-quality-lidar

[29] **Espineira, J. P., Robinson, J., Groenewald, J., Chan, P. H., & Donzella, V. (2021).** *Realistic LiDAR with noise model for real-time testing of automated vehicles in a virtual environment*. https://wrap.warwick.ac.uk/id/eprint/148571/

[30] **University of Southampton. (2021, February 10).** *Silicon chip provides low cost solution to help machines see the world clearly*. https://www.southampton.ac.uk/news/2021/02/compact-lidar-chip.page

[31] **Aston University. (n.d.).** *Laser and Biomedical Photonics.* https://www.aston.ac.uk/research/eps/aipt/laser-and-biomedical-photonics

[32] **University of Glasgow. (n.d.).** *Working with industry – Centre for Quantum Technology*. https://www.gla.ac.uk/research/az/quantumtechnology/workingwithindustry/

[33] **Vector Photonics. (n.d.).** *A revolution in laser technology.* https://www.vectorphotonics.co.uk/

[34] **Compound Semiconductor Applications Catapult. (n.d.).** *Home*. https://csa.catapult.org.uk/

[35] **Custom Interconnect Ltd. (n.d.).** *Home*. https://www.cil-uk.co.uk/

[36] **Phlux Technology Ltd.** (2025). *Phlux Technology – Lowest noise InGaAs APD 1550 nm*. https://phluxtechnology.com/

[37] **ZX Lidars. (n.d.).** *Wind Lidars.* https://www.zxlidars.com/wind-lidars/

[38] **Global GPS Systems. (n.d.).** *Introduction to GNSS IMU systems.* https://globalgpssystems.com/gnss/introduction-to-gnss-imu-systems/

[39] **u-blox. (2024, February 9).** *Network RTK vs PPP-RTK: An insight into real-world performance*. https://www.u-blox.com/en/blogs/tech/network-rtk-vs-ppp-rtk

[40] **GuideNav. (n.d.).** *What is the price of Inertial Measurement Unit (IMU)?* https://guidenav.com/what-is-the-price-of-inertial-measurement-unit-imu/

[41] **Swift Navigation. (2020, February 13).** *Developments in modern GNSS and its impact on autonomous vehicle architectures.* https://www.swiftnav.com/resource/white-paper/developments-in-modern-gnss-and-its-impact-on-autonomous-vehicle-0

[42] **Fitzgibbon, P. (2024, September 24).** *Glasgow spearheads quantum research into resilient Position, Navigation and Timing. GeoConnexion.* https://www.geoconnexion.com/in-depth/glasgow-spearheads-quantum-research-into-resilient-position-navigation-and-timing

[43] **OxTS. (n.d.).** *Products.* https://www.oxts.com/

[44] **VBOX Automotive.** (n.d.). *Products.* https://www.vboxautomotive.co.uk/index.php/en/products

[45] **Zero Point Motion. (n.d.).** *Sensors.* https://www.zeropointmotion.com/sensors

[46] **x-io Technologies. (n.d.).** *Products.* https://x-io.co.uk/products/

[47] **Collins Aerospace. (2022, September 22).** *Collins Aerospace awarded UK programme to develop inertial sensor for future weapons platforms.* https://www.collinsaerospace.com/news/news/2022/09/collins-aerospace-awarded-uk-programme-to-develop-inertial-sensor-future-weapons-platforms

[48] **DataIntelo. (2023).** *Automotive perception sensor market*. DataIntelo. Retrieved from https://dataintelo.com/report/global-automotive-optical-sensor-market

[49] **TechUK. (2023).** *Supporting the UK's automated vehicles sector*. TechUK. Retrieved from https://www.techuk.org/resource/four-policy-actions-to-support-the-uk-s-automated-vehicles-sector.html