Space for Automotive: Use Cases and Market Opportunities

Introduction to the sector

The automotive industry is undergoing deep transformation with the rise of autonomous driving, the increasing ubiquity of battery electric vehicles (BEVs) and unprecedented growth in software-based revenue streams[1]. It is plausible to imagine that the global market could grow dramatically from $3 trillion to $5 trillion by 2030, with potential annual sales volumes reaching $234bn from software-based services alone. This is emerging, on the one hand, as a result of the Internet of Things, with cars embedded in a smart city ecosystem and new infotainment systems becoming available thanks to the latest information possibilities. On the other hand, because of Level 4 fully automated vehicles, i.e. self-driving cars capable of operating without human intervention within specific conditions or environments, the need for complete, constant and widespread connectivity is also producing a radical shift in the business models of the companies involved, akin to the transformation already experienced by mobile phone manufacturers. While the automotive industry has for some time been based on a complex network of companies and suppliers, the sector is in the process of opening up to **new technological solutions and partnerships, including with the software and space industries.** In an ever-competitive international market, car manufacturers, suppliers and new partners are looking for innovative solutions to strengthen their business models in this key sector. Figures from 2022 show that car production was particularly important for China (34.1%), Europe (19.4%), North America (15.2%), Japan and Korea (14.7%) as well as for South Asia (10.8%)[2]. Yet, car manufacturing is but one aspect of the future automotive market, whose focus is shifting towards interactivity with its surrounding, constant connectivity and a variety of after-sales business opportunities with a green and shared mindset. The sector seems to be changing from managing product life cycles to managing user experience.

In the context of the role of connectivity and data exchange, developments in the dynamically evolving New Space industry may present the greatest opportunity for the automotive industry today to bring its future vision into play. Satellite technology has already played an early role in product definition through navigation and narrowband applications. With the advent of the software-defined vehicle, this long-standing relationship with the space industry could become the most significant relationship of all for the automotive industry.

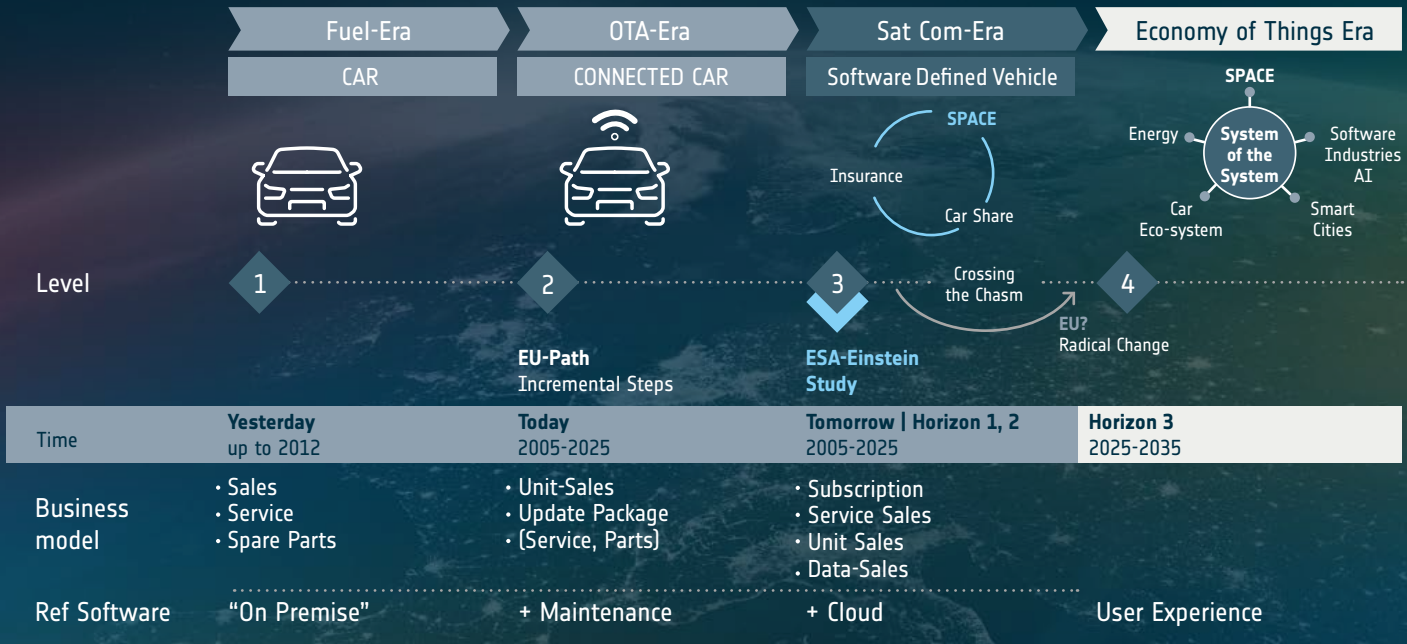


Figure 1: The automotive industry on its way to becoming a system of systems

1.This report is primarily based on the "Assessment of Space-Enabled Applications in the Automotive Sector" by Einstein Ventures, created in collaboration with Porsche Consulting Group and Aciflux, and commissioned by ESA. The original report is available under Space Enabled Applications in the Automotive Sector (einstein-iv.space)

2.Passenger car production, by world region (S&P Global Mobility, 2023)

European automotive landscape and players

The European automotive industry has long been on a successful trajectory and has for some time enjoyed a position as global leader and driver of Europe's growth and prosperity. Both the passenger car – as a cornerstone of individual mobility – and the commercial vehicle – as the backbone of the European economy – contribute to society, the environment, economic welfare and growth in Europe. The turnover generated by the automotive sector represents 7% of the European Union's total GDP; almost 13 million direct and indirect workers in the industry account for 7% of all EU jobs. Some 3.1 million manufacturing jobs, representing 10.5% of EU manufacturing jobs, are in the automotive sector[3]. Vehicle manufacturing is a strategic industry in the EU, where 13 million cars, vans, trucks and buses were manufactured in 2022. Europe is also the **largest investor in automotive R&D and accounts for over 40 percent of global automotive value share** coupled with strong export performance. At the same time, the sector is under strong pressure from international competition, and is subject to technical and regulatory challenges.

One aspect that is propelling the transition to and adoption of BEVs in the European market is the EU's commitment to environmental sustainability. The ambitious target of achieving net-zero emissions by 2050 necessitates a significant reduction in greenhouse gases from the automotive sector. A major contributor to achieving this goal will be electrification and sales of electric vehicles; though they currently make up a small portion of the fleet (14% in 2023), those sales are rapidly increasing[4]. Large manufacturers such as Volkswagen, Daimler, and BMW are also significantly involved with sustainable production efforts. They are adopting renewable energy sources, utilising new technologies and embracing circular economy principles to minimise their environmental impact[5]. New companies are emerging in response to these trends, acknowledging the importance of software-driven features in new products, especially electric vehicles and related solutions.

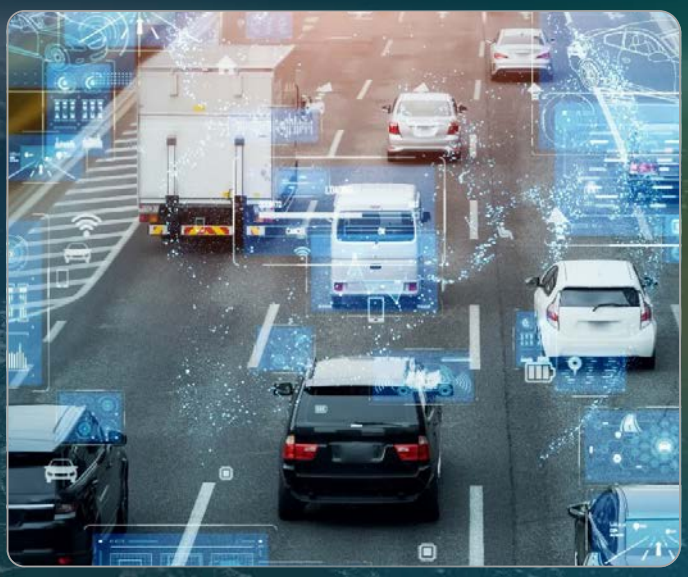
Another major challenge is connectivity as a means of enhancing the driving experience and meeting the evolving needs of consumers. It is estimated that for 12.4% of the time, drivers on major European routes are disconnected, particularly in sparsely inhabited, frequently rural areas[6]. Such disparities underscore the importance of robust infrastructure for the future of autonomous driving. While current vehicles predominantly feature basic advanced driver assistance systems, the landscape is rapidly evolving towards more sophisticated autonomous capabilities. Advancements promise to elevate vehicles to Level 4 autonomous driving, granting them driverless control under specific conditions. In Europe, Germany is setting the pace in regulatory development with its Law on Autonomous Driving, enabling Level 4 autonomous vehicles to operate within specified operational areas on public roads. France has also established a robust legislative and regulatory framework for the deployment of automated vehicles and transport systems.

Market needs and trends

The emerging digital trends in the automotive industry hold immense potential to transform the transportation landscape. These advancements promise to enhance vehicle safety, improve efficiency and offer exceptional convenience to users. However, to fully realise these benefits, several critical areas require careful attention and strategic development.

Robust and resilient broadband connection:

Reliable connectivity is crucial for autonomous driving cars. It not only ensures that passengers can stay connected for work or entertainment but, more importantly, it enables vehicles to make real-time decisions. Continuous data flow from sensors and cameras allows for safe navigation and adaptation to changing road conditions. Internet connectivity also supports essential functions such as remote software updates, ensuring that a car's features remain secure and up-to-date. Resilient internet access also facilitates remote diagnostics, enabling car manufacturers to monitor vehicle health and perform preventive maintenance through data analysis[7]. Yet, as internet connectivity becomes integral to modern cars, ensuring robust cyber security is paramount. Vehicle-to-Everything (V2X) technology can enable seamless information exchange between cars, pedestrians, infrastructure and smart city systems. While this fosters a convenient connected ecosystem, it also enlarges the attack surface for cyber threats. Securing critical systems such as braking, steering and engine control is essential to prevent malfunctions and accidents. Additionally, protecting personal data exchanged in their transmission, including location history and driving behaviour, is crucial.



3.Employment trends in the EU automotive sector (ACEA, 2023)
4.New car registrations, European Union (ACEA, 2024)
5.Assessment of space-enabled applications in the automotive sector (Einstein Industries Ventures, 2023)
6.Automotive white paper (ESA)
7.Assessment of space-enabled applications in the automotive sector (Einstein Industries Ventures, 2023)

Changing infrastructure towards multimodality:

The historical success of the automotive industry was not solely based on vehicle innovations but was also closely tied to infrastructure development, encompassing vehicles, roads, petrol stations and supportive policies. Beginning with the satcom era however, in which the software-defined vehicle is becoming a reality, a completely new mobility infrastructure will become the all-important success factor. An infrastructure of connectivity and data exchange between objects and their environment must emerge. Furthermore, as the industry has become increasingly connected through the internet, it has transitioned from an "on-premise" approach to a "cloud-based" one. As electric and connected vehicles gain traction, building a robust infrastructure is important for a connected ecosystem comprising charging, but also traffic management, road security and optimisation. The automotive industry relies on precise positioning for autonomy, and the integration of satellites for both communication and navigation provides an attractive value proposition for the automotive ecosystem, including multimodality and mobility-as-a-service solutions.

Environmental concerns and emissions footprint:

Reducing environmental impact is a topic of great concern on the production as well as on the usage side. There is the urgent and complex challenge of quantifying, reporting and reducing greenhouse gas emissions within the automotive industry's manufacturing networks. As global climate concerns intensify, the industry acknowledges the imperative need to pivot towards sustainability, primarily through achieving net-zero emissions and ensuring comprehensive environmental transparency. This applies to OEMs (original equipment manufacturers) and key suppliers alike, but also increasingly includes the traceability of raw materials to meet ESG (environmental, social, governance) commitments throughout the supply chain.

Optimal usage of vehicles, in the sense of utilisation rates but also efficiency, is becoming increasingly important. Increasing utilisation and occupation rates are becoming a reality through shared and multimodal mobility – a trend that requires the right supporting technologies. This evolution is particularly influenced by changing values among younger consumers, who are embracing multimodal mobility solutions. These consumers, heavily influenced by the software industry and shared economy models seen in mobile apps, are seeking flexible and convenient transportation options beyond traditional car ownership. In addition, efficiency of usage and cost reduction through increased vehicle health and condition-based maintenance rooted in on-board diagnostics is needed. Route optimisation taking account of road work or traffic are factors to be included in route planning. In order for this transition to occur, automotive companies need to have the capability to continuously monitor vehicle usage to capitalise on it, which can be facilitated by maintaining constant connectivity.

Space sector added value

Public and private advancements are making Earth Observation (EO), Satellite Communications (Satcom) and Positioning, Navigation and Timing (PNT) systems increasingly crucial to the automotive sector's transformation. Overcoming previous technical limitations and accessibility, especially in terms of latency, data throughput and coverage, will further unlock the enormous economic potential that exists.

Advances in Sat EO include improved Revisit time, high-resolution data and various sensor technologies, including multi- or hyperspectral sensors and radar. Accessibility of Sat EO imagery will be improved through APIs, standardised offerings from platform providers and analytics providers benefiting from AI bridging the gap between satellite data and industry-specific use cases.

As with EO, notable changes have developed in the PNT space, mainly concerning emerging dedicated low-cost LEO constellations that could complement existing GNSS (Global Navigation Satellite Systems) systems for high-precision positioning. LEO constellations are accelerating the realisation of automotive industry goals by strategically deploying satellites in clear orbits, while regulatory flexibility is improving operational efficiency and coverage.

Satellite Communications is central to almost half of the relevant use cases identified by the Einstein report. LEO satellite constellations provide global connectivity, and the automotive industry relies on Satcom for connectivity. The growing market demand for satellite connectivity is attracting private sector investors who are challenging traditional regulations.

Space technologies enhance the automotive industry by introducing cutting-edge solutions that improve vehicle performance, safety, and connectivity. The integration of these approaches enables the development of more efficient and reliable transportation systems, contributing to the overall advancement of the industry[8]. The 23 most relevant use cases have a combined potential economic impact of €924bn, as shown by Einstein Space Consulting[9].

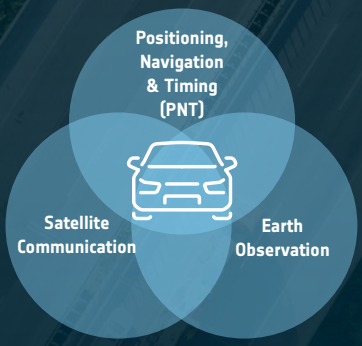
8/9.Assessment of space-enabled applications in the automotive sector (Einstein Industries Ventures, 2023)

Sat Com, EO and PNT € 153.9 bn

- Supply chain transparency & resilience
- Roadworks & forward collision warning
- Real-time traffic control
- Road health & infrastructure monitoring

Sat Com € 55.2 bn

- Backbone, secure communication & teleoperation
- Connecting people



Sat Com & PNT € 645.6 bn

- Auto pilot
- Auto pilot & teleoperation
- Dynamic insurance contract
- Vehicle health & condition-based maintenance
- Entertainment

Earth Observation & PNT € 68.9 bn

- Production network emissions footprint
- Productivity competition monitoring
- ESG compliance

Figure 2: Economic impact of meshed 23 highest-rated use cases

RELEVANT USE CASES APPEAR IN THE PRODUCTION AS WELL AS THE PRODUCT AND USER CYCLE.

Supply chain and production:
Building a greener future requires a sustainable supply chain. Space-based solutions offer a powerful tool to achieve this goal. By continuously monitoring production networks with satellite imagery, manufacturers can track emissions and ensure compliance with environmental regulations. Furthermore, real-time PNT data combined with satellite communication streamlines component deliveries, reduces lead times, and fosters a just-in-time production model, minimising waste.

Improvements in battery efficiency and sustainability, including recyclability, are focus of many developments. Under ESA Technology Transfer activities, Atos IT Solutions and Services GmbH[10] is aiming at spinning technology developed for space off into the automotive sector: This technology is ProUST univerSAS®, comprising fully digital power supply which is compact, with more than 16 kW power output and 2HU (about 10 cm) in size. Other development activities targeting space batteries that could also be used by automotive industry, include e.g. materials for increase in fire safety and decrease in weight, taking into account anticipated REACH / RoHS obsolescence issues. The automotive industry could also benefit from stringent approaches to battery testing developed for space applications.

After-sales and mobility services:
Condition-based maintenance, a proactive maintenance strategy that utilises real-time monitoring to determine the optimal timing for maintenance activities, uses internet connection by satellite to constantly monitor vehicle health. Paired with accurate PNT systems, this proactive approach helps vehicles efficiently locate nearby service stations. Space technologies are instrumental to embracing innovative business models such as rent-by-hour services and peer-to-peer sharing. Through GPS, companies can obtain precise positioning information, enabling them to monitor vehicle or asset location in real-time. Moreover, this analysis allows for the examination of driving behaviours and the recognition of patterns in users' driving styles, which could be useful for various purposes such as improving driver safety, optimising fuel efficiency, enhancing route planning and identifying areas for driver intervention.

Infrastructure and charging:
The development of charging infrastructure is closely linked to the utilisation of space technology. Utilising real-time satellite data enables the identification of optimal locations for new charging stations by analysing traffic patterns. As we move towards sustainable energy and smarter grid systems, vehicles might play a crucial role in balancing supply and demand. Satellite data, which can predict power needs by considering factors such as weather and traffic, provides valuable information for charging station usage. Additionally, ensuring a reliable power supply is equally important. Identifying locations with easy access to existing power lines is essential.

EV8 Technology[11], a company dedicated to streamlining the transition to electric vehicles, developed the EV8 Switch app with the support of the European Space Agency's BASS program. This app leverages GNSS satellite data to analyse users' real-world driving habits and assess the suitability of an EV for their needs. By providing personalised insights based on actual driving patterns, the project aims to reduce confusion and encourage informed decision-making for potential EV adopters. The project resulted in a free app being made available on mobile platforms and a separate web-based dashboard for fleet managers, offering valuable data on range requirements and driving behaviours.

Vehicle fleet data & control:
By creating smooth links between automobiles and OEMs, communication enables real-time vehicle health monitoring. Automotive manufacturers can guarantee adherence to environmental rules and optimise vehicle performance based on particular environmental circumstances by utilising satellites to perform accurate measurements. Automobile manufacturers can tailor cars to specific regions using detailed data, ensuring better alignment with sustainability policies in each area.

10.Website: Atos IT Solutions and Services GmbH
11.Website: EV8 Technology

ANavS[12] is a company incubated at the ESA BIC Bavaria, which developed the Integrated Sensor Platform (ISP) to address the challenges faced by autonomous vehicles. The focus of the project is to create a reliable and precise reference system for autonomous driving. This is achieved through a multi-sensor approach including GNSS receivers, inertial sensors, wheel odometry, cameras and a lidar detector. Sensor fusion with an extended Kalman filter is used to provide highly accurate positioning even in difficult environments with limited GNSS signal. Additionally, the ISP leverages camera and lidar data for SLAM (Simultaneous Localisation and Mapping) to create detailed 3D maps and perform real-time object detection and tracking. This information, including object position, bounding boxes and classification, is crucial for autonomous vehicles to be able to navigate safely.

Figure 3: Integrated Sensor Platform (ISP) of ANavS

In-vehicle user services:

As the entertainment industry advances, cars are becoming extensions of personal entertainment spaces, with a growing demand for high-quality experiences such as gaming and video calls. Carmakers could charge extra for these services, offering on-demand upgrades through OTA updates in the realm of passenger health monitoring and advanced gaming features. This requires strong broadband connections, emphasising the need to integrate satellite communication technologies for seamless and secure access.

Vehicle-to-Everything (V2X):

By facilitating seamless communication between vehicles and external entities, V2X empowers smarter traffic management and accident prevention strategies. Satellite communication ensures secure connections, a critical element for tasks such as automated platooning and real-time roadwork alerts, mitigating risks including signal jamming and hacking. Additionally, V2X data offers valuable insights for insurance companies, allowing for customised policies based on real-time driving behaviour. Moreover, this connectivity lays a crucial foundation for the advancement of autonomous driving technologies. With V2X capabilities in place, vehicles can communicate not only with each other but also with infrastructure and other road users, enhancing the overall safety and efficiency of autonomous driving systems.

Darwin Innovation Group[13], founded in 2019 with the goal of achieving reliable and widespread connectivity in autonomous driving, has developed a solution that combines terrestrial and satellite communications to overcome the limitations of each. Crucial to their success has been the support of the European Space Agency under the 5G/6G programme, which provided both funding and expertise to carry out the project. Traditional terrestrial networks often fail in remote areas or when a car moves in and out of range. Satellite networks, on the other hand, offer broad coverage but can be expensive and complex to integrate. By combining these technologies, Darwin's Hybrid User Terminal seamlessly switches between networks, ensuring a constant connection for users on the move. This is particularly important for connected and autonomous vehicles. By gathering data from these vehicles, they are not only improving their own services but also helping partners in the insurance sector, such as Aviva. With reliable connectivity, these vehicles can bridge gaps in rural public transport, reducing both dependence on single-occupancy vehicles and emissions.

Figure 4: Darwin Innovation Group's autonomous shuttle

Further information on space added value can be found in the original study by Einstein Ventures "Assessment of Space-Enabled Applications in the Automotive Sector" or the automotive white paper issued by the Directorate of Connectivity and Secure Communications.

By providing both funding and expertise, ESA is helping private companies harness space technologies to tackle some of the most pressing transportation challenges, specifically in the transition to electric vehicles and the development of autonomous driving systems. ESA supports the expansion of the automotive sector through commercial initiatives such as the Business Applications Space Solutions, the ESA BICs, Technology Transfer, ARTES, InCubed and FutureEO.

12.Website: ANavS
13.Website: Darwin Innovation Group