Routes to Market Report

06 - Satellite Technologies for Broadband to Vehicles

Innovate UK

CATAPULT Satellite Applications

Contents

1. Introduction and Scope

This report covers the global Satellite Broadband to Vehicles sector, with an emphasis on the UK and European markets. The general technologies covered include the Global Navigation Satellite System, including GNSS and Galileo, and Satellite Communications, including Vehicle-to-Vehicle Communications.

The report will cover the near-term period from 2016 to 2020 and the long-term period to 2030. The purpose of the report is to identify opportunities for UK space companies within the Satellite Broadband to Vehicles channel, as well as the key market trends and drivers.

2. Market Overview and Opportunities

There are a number of opportunities for satellite applications to address the needs of the connected vehicle market. Combined with terrestrial networks, satellite offers the ability for service providers (in partnership with the vehicle manufacturers), to offer a seamless and always on connectivity solution. Areas of opportunity for UK space companies include –

- Vehicle to Vehicle (V2V) applications: Communications, Over the Air (OTA) Software Updates, Emergency Response, Automobile and Air Traffic Control
- City Infrastructure
- Autonomous Operation

2.1. Vehicle-to-Vehicle Satellite Communications (V2V)

Vehicle to vehicle communication is the transmission of data, between motor vehicles themselves, and/or via a central control centre, through a wireless medium. The data would include information on the current vehicle status, such as location, speed, direction of travel, loss of stability, and braking activity. The range of dedicated short-range communication (DSRC), a technology which is currently used by vehicle to vehicle communication technology, is standardised by bodies like the Federal Communications Commission(FCC) and the International Organisation for Standardisation, (ISO) and has a range of up to 300mtrs or 1000mtrs, (or 10 seconds at highway speeds). Currently, this connectivity is largely provided by terrestrially based solutions which often have data and coverage limitations. To maintain an always on service, there are evident opportunities for satellite based assets and applications to improve or complement against these shortfalls.

The main goal of vehicle to vehicle communications is to prevent accidents by enabling communicating between vehicles over an available data network. For example, depending upon the implementation of technology, the driver is warned about the risk ahead and instructed to slow down accordingly. Vehicle to vehicle communication gives all-round information of risks and is expected to be more effective by interfacing with technology such as adaptive cruise control, blind spot detection, rear-parking sonar, blind spot detection, lane departure, and the reversing camera.

The vehicle to vehicle communication market can be segmented based on technology and types of devices. Based on technology, vehicle to vehicle communication applications can be further segmented into, e.g. big data analytics, smart sensors and cloud computing. For example, vehicles

with access to cloud storage would enable them to access software updates, libraries of maps, self-guided tours, and navigational shortcuts. Big data analytics and data science would help the vehicle manufacturing companies to better understand their customers by identifying future opportunities, and anticipating relevant requirement development. Sensors would help in sensing traffic volumes thereby enhancing the ride quality and experience of the vehicle's occupants. Sensors are used to augment accuracy and V2V technology could act as an additional sensor that could augment the data available.

Based on types of devices, the V2V communications market can be segmented into OEM devices, aftermarket devices, and infrastructure-based devices. An OEM device is built or integrated into the vehicle during vehicle production. Aftermarket devices are devices which may not be fully integrated to the vehicle at times of manufacturer, but added later. Infrastructure based devices involve the need for exchange of secure information and operational data between vehicles. Satellite based applications have a role to play in this important area. Aftermarket services could be complemented with satellite applications. For example, using satellite connectivity to send vehicle recall software updates and information over satellite networks could vastly reduce manufacturers recall costs, (80% of vehicle recalls are software updated based).

Major vehicle manufacturers are now delivering motor vehicles with connected services for drivers, including real-time traffic and weather reports and accident or road works warnings. More applications are on the way, and the technology systems that support them will enable the increasing number of autonomous vehicles that will soon be driving on our roads and motorways. Satellite broadband and positioning applications, (and UK Space companies providing these services), can benefit greatly from the rapid growth in the connected vehicle revolution.

2.2. Vehicle-to-Vehicle Communication: Emergency Response

Vehicle to vehicle satellite communications can be used to automatically alert nearby emergency vehicles when a vehicle on the road is acting abnormally. This system would improve the safety of both the abnormal vehicle and surrounding vehicles which may be endangered by the abnormal vehicle, preventing a possible collision.

Using V2V communication, when a vehicle on the road acts abnormally, (e.g., deceleration exceeding a certain threshold, dramatic change of moving direction, major mechanical failure, etc.), it becomes an "abnormal vehicle" (AV). An AV actively generates Emergency Warning Messages (EWMs), which include the geographical location, speed, acceleration and moving direction of the AV, to warn other surrounding vehicles. A receiver of the warning messages can then determine the relevancy to the emergency based on the relative motion between the AV and itself.

However, the link qualities in current V2V communications can be inconsistent due to multipath fading, shadowing, and Doppler shifts caused by the high mobility of vehicles. An assessment of the performance of a wireless LAN in different vehicular traffic and mobility scenarios shows that the deterioration in signal quality increases with the relative and average velocities of the vehicles. Augmentation with satellite connectivity could vastly reduce the potential for the loss of a connection. Besides unreliable wireless links, packet collisions caused by MAC layer can also contribute to the loss of EWMs. Moreover, in an abnormal situation, all vehicles close to the AV may

be potentially endangered and they all should receive the timely emergency warning. But the group of endangered vehicles can change quickly due to high mobility of vehicles. For example, at the time of emergency event at vehicle A, the nearby vehicles are put in potential danger. Very soon, vehicles may pass and should no longer be interested in the emergency warning. Meanwhile, vehicles can get closer and closer to vehicle A and should be informed about the abnormal situation.

Both the unreliable nature of wireless communication and the fast changing group of affected vehicles create challenges for satisfying the stringent EWM delivery delay constraint in cooperative collision warning. UK Space companies could further develop and implement V2V satellite communication technology to provide solutions to wireless communication issues for emergency responders.

Emergency response vehicles (ERVs) frequently navigate congested traffic conditions to reach their destinations as quickly as possible and vehicle to vehicle satellite connectivity, (both data and positioning), can be used to navigate traffic and facilitate safe and efficient ERV travel.

Micro-simulation of a network based on a Northern Virginia, USA Connected Vehicle test bed examined the effect of a variety of factors on ERV travel time, including the presence of vehicle-to-vehicle communication, traffic volumes, cycle length, ERV speed distributions, non-ERV speed distributions, and traffic signal pre-emption. The results indicated that effective and always on V2V communication could reduce travel time for an ERV in congested traffic conditions.

Finally, employing GNSS capabilities in vehicles allows emergency response vehicles to automatically locate the source of an emergency call in situations where phone reception is unavailable, such as in remote areas.

2.3. Vehicle to Vehicle Communication: Automobile and Air Traffic Control

A valuable market opportunity for the use of Vehicle to Vehicle Satellite communications lies in the application of this technology for automobile and air traffic control, (an aircraft is a vehicle, even if it is not land-based for most of its operational time).

For vehicle and air traffic control, satellites and associated ground communications stations are today the most reliable, secure and efficient way of transmitting data and voice between the different components of vehicular and traffic management infrastructure at national or continental level.

Efficient datalink services allow vehicle and flight plans that can be continuously updated to maintain the best path to destinations. For aviation, air traffic control can offer better routings, sequence aircraft far in advance, and maximise airport and airspace capacity. In addition to reducing flight times and airborne holding, it will also support continuous descent, reducing fuel consumption, delays and carbon dioxide emissions.

Indeed, Leo Mondale, President at Inmarsat Aviation, said: "Air traffic management is under great pressure and there is no doubt that the digitalisation of cockpit communication is a vital building block of the future.”

Additionally, Giancarlo Schisano, Chief Operations Officer at Alitalia, said: "We believe that satellite communications represent the natural development of the industry and will lead to concrete benefits to airlines and their travellers due to reduced flight times, more savings on fuel consumption and even more advanced flight safety."

With road vehicles, V2V communications can significantly reduce traffic congestion and thus create speedier and more efficient road transportation of people and goods. This technology can also reduce collisions, improving the safety of road travel.

As an example of how this technology can benefit drivers, Audi is introducing a new set of services that are designed to work in the cloud and offer advanced benefits in the vehicle. The company plans to introduce Traffic Light Online, a service which connects the car to traffic light infrastructure and provides information in the vehicle that guides the driver to drive at a certain speed to be able to get green signals over their route or while stopped at a traffic signal to know how long before a red light turns to green.

2.4. Global Navigation Satellite Systems

Integrated GNSS systems provide more than just positioning and navigation. For example, with GNSS a wide range of other key services are made possible, including:

- Precise navigation systems
- Autonomous vehicles and assisted driving
- Cooperative IT systems
- Usage-based insurance schemes
- Road pricing and congestion charging
- Automated eCall distress signals
- Intelligent speed adaptation

As to the use of GNSS within the connected vehicle, the trend is for manufacturers to take a more important role within GNSS-related services. In fact, by 2020 more and more vehicles with built-in GNSS and fewer 'nomadic devices' like portable GNSS receivers will be coming onto the market. This trend is already being seen in prototype autonomous driving cars, where GNSS is viewed as a fundamental enabling technology.

2.5. City Infrastructure

Across Europe, the number of smart cities is multiplying. To tackle their growing needs and to guarantee efficient city planning and maintenance, many cities are engaged in massive investments in such key areas as street lighting, road maintenance, traffic and waste management.

In parallel, public transportation is continuously evolving in terms of coverage, comfort and technology. Within this context, the exploitation of Galileo and its integration with other sensors is key to developing concrete solutions for current and future smart-city planning. Along these lines, the Horizon 2020-funded GHOST (Galileo Enhancement as Booster of the Smart Cities) project is

designing, developing and validating an intelligent system for vehicles that equips existing public transport fleets with a Galileo-enabled camera and connects these vehicles to a web portal.

The system automatically takes pictures of predefined points of interest (POI) based on the accurate position of the vehicle, provided by Galileo. All images are sent to a processing server capable of detecting such anomalies as potholes or a burnt-out street light. The system then uses the web portal to report these findings to the relevant authorities.

At this point, GHOST is designed primarily for reporting street lighting anomalies and road deteriorations, monitoring public garbage collection and detecting double parking infractions or disabled parking bays occupied by unauthorised vehicles," said Project Coordinator Claudia Maltoni. "In addition to these basic functions, we have also identified more advanced services, such as spotting bus-lane and congestion-charging-area violations, which will be implemented at a later date."

The GHOST system's key differentiator is its use of Galileo positioning, which gives it the capability to take autonomous snapshots with an error range of 1 to 10 meters (depending on the size of the POI). In densely populated urban environments, such a level of service is only possible with the combined use of Galileo, inertial sensors and Kalman filters.

By taking advantage of the many vehicle movements happening in cities every day, GHOST proposes a competitive way to improve the efficiency of monitoring a city's operations and infrastructure. Once finalised, the system will enable faster detection of double parking or road deterioration and help reduce traffic, accidents and pollution.

The emerging application of Galileo positioning within vehicles to improve city infrastructure provides a valuable market opportunity for UK Space companies.

2.6. Autonomous Operation

Connected and autonomous vehicles will change the way in which many of us commute. They offer the promise of saving time and money, getting people and goods to their destinations faster and more easily, and aiding mobility for disabled and older people. They have the potential to reduce collisions, and could save over 2,500 lives and prevent more than 25,000 serious accidents a year. It is also predicted that eventually we will no longer need driving licences or insurance, or even own our own cars; users will just book a vehicle journey via an application.

The overall economic and social benefits of connected and autonomous vehicles are predicted to be in the region of £51 billion per year by 2030 and an additional 320,000 jobs in the sector for the UK alone. Driverless cars will not appear overnight, however. By 2030 all cars will feature connectivity in some form, but only around 25% of vehicles are likely to be highly or fully automated.

Satellite connectivity and positioning will play an important role in the connectivity and autonomy of driverless cars, and the Satellite Applications Catapult is already involved in initiatives to ensure that developments offer the best solution for both users and UK companies. There are significant claims around the value of the market for autonomous and connected vehicles. These range from social

and economic benefits to the UK of over £50bn a year by 2030, to an estimated market for intelligent mobility of £900bn worldwide by 2025.

This market includes semi-autonomous vehicles, which might incorporate features like parking assistance, autonomous emergency braking and cruise control, as well as vehicles that can drive without any human assistance. It also includes the communication and data systems that allow them to operate, which is where much of the potential value lies.

Many government initiatives are already under way to harness the opportunities in this sector. These includes the UK' Spring Budget 2015 announcement of £100m towards the development of autonomous vehicles (match-funded by industry to £200m), three driverless car projects, a UK Code of Practice and a review of domestic legislation relevant to autonomous vehicles. The challenge is to ensure that the UK can generate a productive and sustainable industry from the measures it takes.

Additionally, the UK Government plans a new transport law to spur everything from the country's first spaceport to the production of drones, driverless cars and electric vehicles. The measures aim to reduce congestion that costs the British economy 20 billion pounds ($29 billion) a year, while boosting the country's satellite industry and vehicle exports. Trials of driverless cars are already under way in Bristol, Milton Keynes, Coventry and Greenwich with plans for vehicles, both pods and cars, to drive themselves later this year.

"Modern transportation can make much more efficient use of our roads, railways and airspace, cutting congestion, speeding up journeys for people and goods and boosting our world-leading satellite industry," the government said. The law "will put the UK at the forefront of safe technology in the autonomous vehicles industry, such as drones and space planes."

There is already a staggering level of connectivity and autonomy in vehicles compared to just a decade ago. Autonomous emergency braking and lane assist technologies provide safer driving, and internet connectivity over mobile networks can keep vehicle occupants connected to the online world. Government backing of this agenda is a key component for the UK's future success. The development of a supportive regulatory framework, investment in digital infrastructure and government funding for R&D in this area, as demonstrated by the £200 million for intelligent mobility announced by the Chancellor of the Exchequer in the 2015 Budget, has been welcomed by industry. This growth in connected vehicle applications and initiatives, requiring reliable, cost effective and resilient connectivity, offers a great opportunity for UK space companies.

3. Customer and End-User

The customers and end-users of Vehicle to Vehicle Communications are:

- Vehicle manufacturers
- Drivers and passengers
- Emergency responders
- Traffic controllers
- Pilots

The customers of Autonomous Vehicle Satellite technology are automobile companies, while the end users are drivers. Currently, user maturity is quite low in this segment because driverless cars have not yet been fully introduced to the market. The challenge for automobile companies will be to build up consumer confidence and trust in autonomous vehicles between now and 2020, when automobile companies are planning to introduce driverless vehicles to the mainstream market.

The consumers and end-users of the application of satellite broadband for vehicles to improve city infrastructure would be city governments as well as the residents of the city.

4. Value Proposition to Customer and End User

4.1. Proposition for Vehicle to Vehicle Communications

- Delivering bandwidth to the "connected vehicle" offers a major market opportunity for communications companies while at the same time giving auto manufacturers a more efficient way to update in-vehicle software on computers that are increasingly vital to vehicle operations.

- Satellite connected vehicles will improve safety and control congestion in cities. On the roads, vehicles would communicate and send alerts if a crash was deemed imminent. These features would attract safety conscious customers, increasing their safety and the enabling of easy to drive vehicles.

- The technological advancements giving rise to efficient and cost-effective methods of satellite based communication, (e.g. HTS and Galileo), between vehicles is likely to impel the market growth over the foreseeable future.

- These V2V communication systems generate more and more dat. If a consumer chooses to share it, there is huge potential for development of tailored services and end game products for sectors such as food, retail market and many more industries interested in vehicle movements. This will become a technological advantage for, and a source of competition, to OEM service and technology providers who work in traffic flow management environments.

- The forward and reverse collision detection systems are key enablers for the V2V systems market as they help to prevent accidents. Insurance companies could be interested in ensuring vehicles are fitted with such technology.

- Satellite is the ideal technology to take the connected car to the next level. This is because, unlike local and regional LTE networks, satellite systems are global. Companies like Inmarsat have satellites that reach 99% of the world's populated regions. A homogenous global satellite network is ideally suited to the world's car manufacturers, most of which sell cars on every continent. With satellite, companies like Toyota, Honda and Ford can reach all their vehicles on a single network, whether the cars are in Canada or South Africa. Furthermore, satellites can reach rural areas that don't have cellular service.

Having the global communications platform of satellites will be a distinct advantage over LTE networks. In the next five years, more than 220 million connected cars will be built and sold around the world. How those cars are connected will be fundamental to the communications they can receive and send, not to mention the economies of scale for car manufacturers. For example, having the same antenna technology (like that Intelsat is developing in partnership with Kymeta) in a car in Uruguay, the United States or the UK will be a great enabling factor.

- Distribution of huge amounts of Data to a vehicle: The ability to send software and firmware updates to computers on board vehicles will be a boon for car manufacturers. Multicasting like this can both eliminate the need for an owner to bring a car into a dealership for a routine maintenance check and speed the response to manufacturer recalls. Manufacturers can efficiently respond to the need to fix bugs in software or provide update patches or rectify systems after a cyber-attack.

- Broad Coverage and Global Deployment: With global coverage and high speed everywhere (vs. 2G and 3G in most places and 4G in few areas), satellite has a distinct advantage over cellular in terms of network consistency. With a global network like Inmarsat's, car manufacturers benefit from a single network. With a cellular network, they would work with hundreds of terrestrial carriers and need to access multiple distinct technologies around the world for any kind of data broadcasting. Satellite can offer a private or dedicated network from the original source to the vehicle, anywhere in the world.

- Stable and Secure Communications: Satellite's ability to provide a global, private network offers vehicle manufacturers a consolidated distribution opportunity that reduces attack vectors by eight or nine orders of magnitude when compared to cellular in terms of entry and exit points. While privacy issues need to be resolved, insurance providers, car rental companies and others will be able to monitor driver behaviour. Cars already have the equivalent of a "black box" that records operational data. With a satellite connected car, this information could be streamed in real-time to a central location. While some motorists might not want their driving monitored, others might want an insurance discount for safe driving.

- Cost Efficient: In the case of the connected car, it is not the cost-per-bit delivered that matters most, but the value of the content. Since the cost of content is largely independent of the number of receivers, the distributor's expense to provide content from a satellite broadcast or multicast is the same whether there are 5 receivers or 50 million.

- Multicast Over the Air Update capability: Anupam Malhotra, Director, Connected Vehicles at Audi of America, recently stated that satellite technology has a distinct advantage over other technologies, is the amount of data that can be transferred at a single time, to multiple users.

"With a single stream, you are immediately populating the entire nationwide geography. We moved away from satellite technology for traffic services to the online system, because we

needed to have the two-way communication channel with low latency, and because the download channel was creating a processing headache within the vehicle due to the large amount of non-local data. But where this capability does become very useful is when we look at things like OTA updates. It is yet to be determined what the right process will be for this; in fact, we have been quite successful launching OTA updates for items like map data over the cellular channel. But these services must be designed carefully to not break carrier network management thresholds," he says. Satellite communications overcomes these bandwidth challenges.

- In Europe, satellite could play a part in the rollout of the Emergency Call (Ecall) safety service, scheduled to be launched by late 2017 across Europe.

"If you look at the statistics, some of the worst car accidents are in remote areas, and these areas may not have phone reception. So, this is where satellite technologies can step in and fill the void in some core services like that," says Andrew Lee, principal consultant for automotive and transportation at Frost & Sullivan

4.2. Proposition for Autonomous Vehicles

- "Autonomously-equipped vehicles will improve the safety and well-being of drivers, with fewer collisions and reduced traffic congestion," said Paul Wilcox, chairman of Nissan Europe. "The UK economy can also benefit, by playing a pivotal role in a global industry estimated to be worth 900 billion pounds by 2025."

- The overall economic and social benefit of connected and autonomous vehicles could be in the region of £51 billion per year by 2030.

- Connected and autonomous vehicles could create an additional 320,000 jobs in the UK by 2030, 25,000 of which would be in automotive manufacturing.

- By 2030, connected and autonomous vehicles could save over 2,500 lives and prevent more than 25,000 serious accidents in the UK alone.

- Fortunately, the UK is well positioned. The UK has unrivalled strengths in many of the key areas integral to the development of connected and autonomous vehicles: advanced engineering, systems integration, digital technology and software development and of course a vibrant downstream Space sector.

4.3. Proposition for Satellite Communications for Automobile and Air Traffic Control

- Satellites and associated ground communications stations are today the most reliable, secure and efficient way of transmitting data and voice between the different components of a vehicular or air traffic management infrastructure at national or continental level.

- Efficient datalink services allow flight plans that can be continuously updated to maintain the best path to the destination. As a result, air traffic control can offer better routings,

sequence aircraft far in advance, and maximise airport and airspace capacity. In addition to reducing flight times and airborne holding, it will also support continuous descent, reducing fuel consumption, delays and carbon dioxide emissions.

- A central network management system allows the user to have a full control of its network and a comprehensive monitoring tool to supervise all events taking place during full-time operations.

- Traffic control for vehicles on the road will lead to reduced traffic congestion, enabling faster transport of people and goods, reduced collisions and improved safety and efficiency of road travel.

5. Market Competitiveness

GSM and Networks offer an obvious alternative to satellite for vehicular connectivity solutions. However, as previously mentioned, they have limitations in terms of coverage and throughput.

In terms of GNSS alternatives. There are number of alternatives, also -

5.1. Lidar

LIDAR, an acronym of Light Detection and Ranging, (sometimes Light Imaging, Detection, And Ranging) and was originally created as a portmanteau of “light” and “radar.”

LIDAR, or optical sensors, is the primary alternative technology to GNSS, as it can be used for identifying the positioning of autonomous vehicles. LIDAR is a surveying technology that measures distance by illuminating a target with a laser light.

LIDAR systems are currently large and expensive systems which must be mounted outside of vehicles. The system Google uses is in the range of 80 kg and $70,000, for example, and must be mounted on top of the vehicle with unobstructed sight lines. Due to their current limitations, the systems are not useful for detecting anything near the car. Current implementations have improved range substantially from early 30 meter ranges up to 150 to 200 meter ranges, with increases in resolution as well. At present, production systems with higher range and resolution continue to be expensive. LIDAR works well in all light conditions, but starts failing with increases in snow, fog, rain, and dust particles in the air due to its use of light spectrum wavelengths. LIDAR cannot detect colour or contrast, and cannot provide optical character recognition capabilities. Narrow-beam LIDAR has been used for 20 years, but current-generation LIDAR used on autonomous cars is less effective for real-time speed monitoring.

Other alternative types of sensors that may be used for autonomous cars include radar, ultrasonic, and passive visual. These systems are expensive and satellite bands systems are more cost effective, reliable and resilient versus these alternatives.

5.2. Radar

Solid-state radar-on-a-chip systems are common, small, and inexpensive. They have good range, but poorer resolution than other sensors. They work equally well in light and dark conditions, and 77 GHz systems can better sense through fog, rain, and snow, which causes LIDAR and passive visual systems challenges. Like LIDAR, no colour, contrast, or optical character recognition is possible with radar. Radar is very effective at determining relative speed of traffic in current implementations. While sensor size makes these better for near-proximity detection, they are less effective than sonar at very short distances.

5.3. Ultrasonic

Ultrasonic sensors actively emit high-frequency sound above the level of human hearing. They have very poor range, but are excellent for very-near-range three-dimensional mapping, as sound waves are comparatively slow, so differences in a centimetre or less are detectable. They work regardless of light levels and, due to the short distances, work equally well in conditions of snow, fog, and rain. Like LIDAR and radar, they do not provide any colour, contrast or optical character recognition capabilities. Due to their short range, they aren't useful for gauging speed. They are small and cheap.

5.4. Passive Visual

Camera image recognition systems have become very cheap, small, and high-resolution in recent years. They are less useful for very close proximity assessment than they are for further distances. Their colour, contrast, and optical-character recognition capabilities give them a full new capability set entirely missing from all other sensors. They have the best range of any sensor but that's in good light conditions. Their range and performance degrades as light levels dim, starting to depend — as human eyes do — on the light from headlights of the car. In very bright conditions, it is apparently possible for some implementations to not identify light objects against bright skies, which was reportedly a factor in the May 2016 Tesla Autopilot-related fatality in Florida. Digital signal processing makes it possible to determine speed, but not at the level of accuracy of radar or LIDAR systems.

Passive visual has the longest range and best acuity when conditions allow it to be used; it degrades rapidly in terms of the quality of information it can provide under adverse conditions. Radar, while not the best sensor under all conditions, degrades the least at ranges necessary to detect vehicles and other objects at higher speeds. LIDAR is better until significant atmospheric murkiness occurs with fog, snow, or heavy rain, but degrades under those conditions.

6. Role of UK Companies

UK Space companies cover a wide range of disciplines.

UK Space companies such as Inmarsat, Avanti and the UK offices of Intelsat and SES, (and others) could benefit from the growth in the connected vehicle sector. These organisations provide the mobile broadband solutions that can provide the necessary coverage, resilience and reliability to ensure always on connectivity. Low and higher data solutions at L and Ka-Band ideally meet the requirements of the connectivity required to meet the applications bandwidth requirements.

Companies that resell GNSS services can also benefit from integrating their services into the OEM manufacturing build of these services as well as any after-market services.

Manufacturers of flat panel or low-form factor antennas can also benefit from the growth in the satellite connectivity to vehicles market.

Systems integration companies such as CGI can work with the automotive manufacturers to ensure that any satellite connectivity is integrated with terrestrial networks, the vehicular software systems and overcome such challenges as rain fade or latency.

7. Revenue Projections

	2016	2017	2020	2022	2030
Vehicle-to-vehicle communications	US$162.22 million	US$ 170.34 million	US$197.19 million	US$217.4 million	US$321.19
Navigation systems	US$60.04 million	US$66.03 million	US$87.84 million	US$106.25 million	US$227.43 million
Connected /autonomous vehicles	US$4.333 billion	US$5.4 billion	US$10.37 billion	US$16.06 billion	N/A

The estimated revenue for UK space companies has been estimated for each market sector by taking 10.3% of the global market sizes for each market.

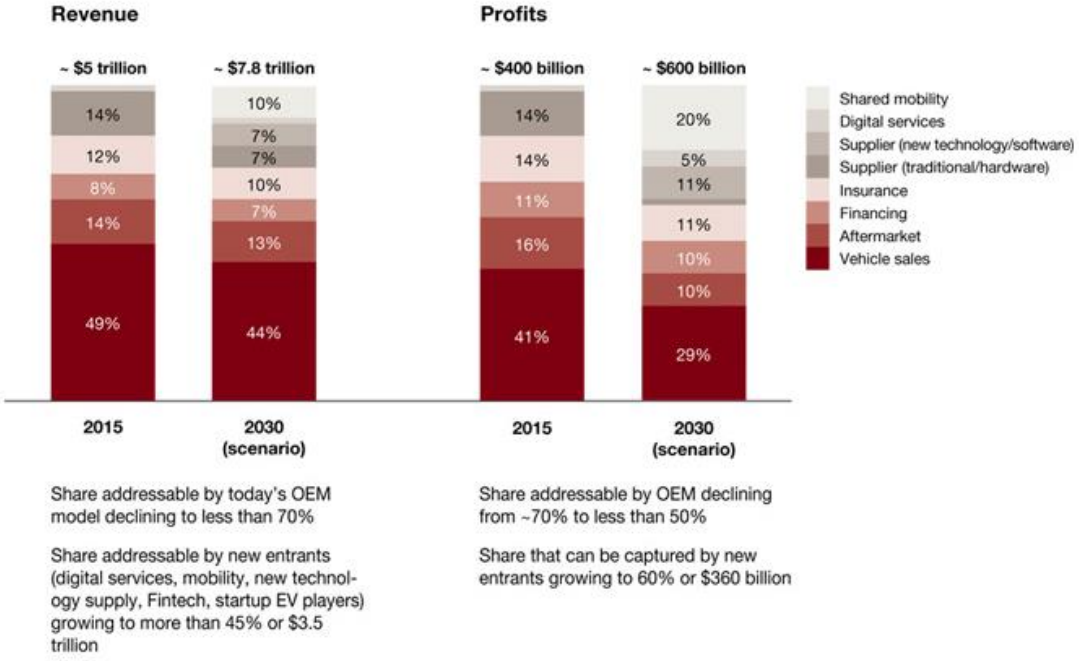
The figure 10.3% was derived from a report by London Economics on the economic impact of Britain's space industry, which found that Britain's space companies have 11.2% of the international operations market for space vehicles, and 10.3% of the applications market for the services and data provided by satellites. Overall this means the UK has 6.3% and 7.7% of the global space industry's annual turnover, which is estimated at about £160bn a year.

The following market size estimates were used:

The global V2V communication market was worth USD 1.5 billion in 2015 and is estimated to exceed at a CAGR 5% by 2024 because shifting trends towards technology side and safety side's methods.

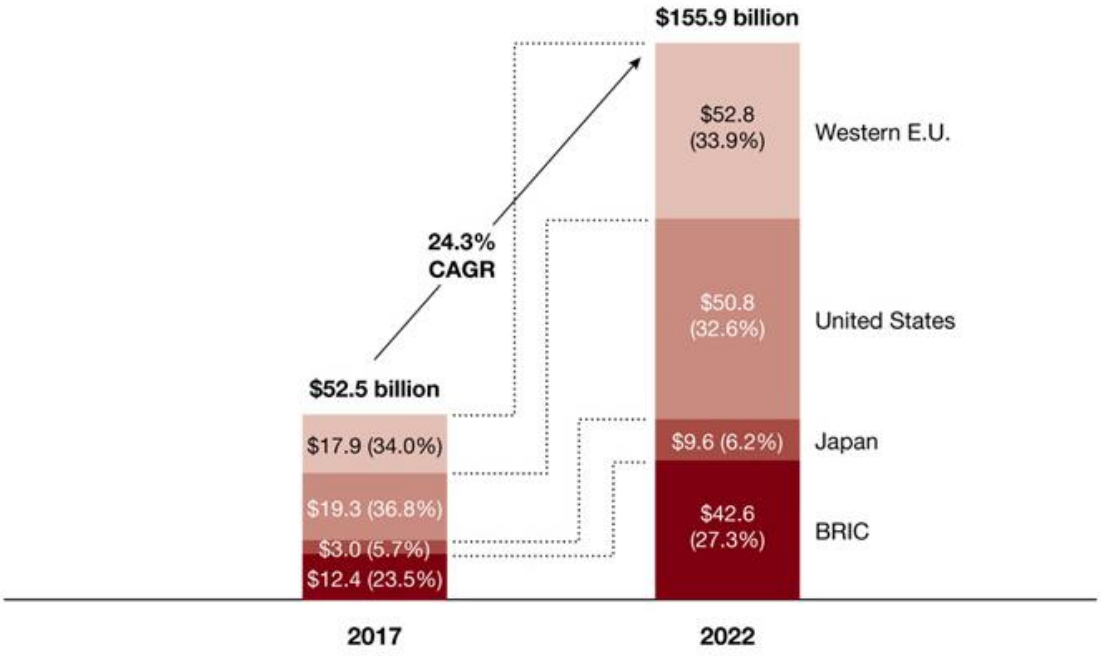
The global navigation systems market is poised to grow at a CAGR of 9.98% over the forecast period to reach USD 937.96 million by the end of 2021, from the current market size of USD 582.93 million in 2016

Exhibit 1: Scenario for value shifts in the auto industry, 2015–30



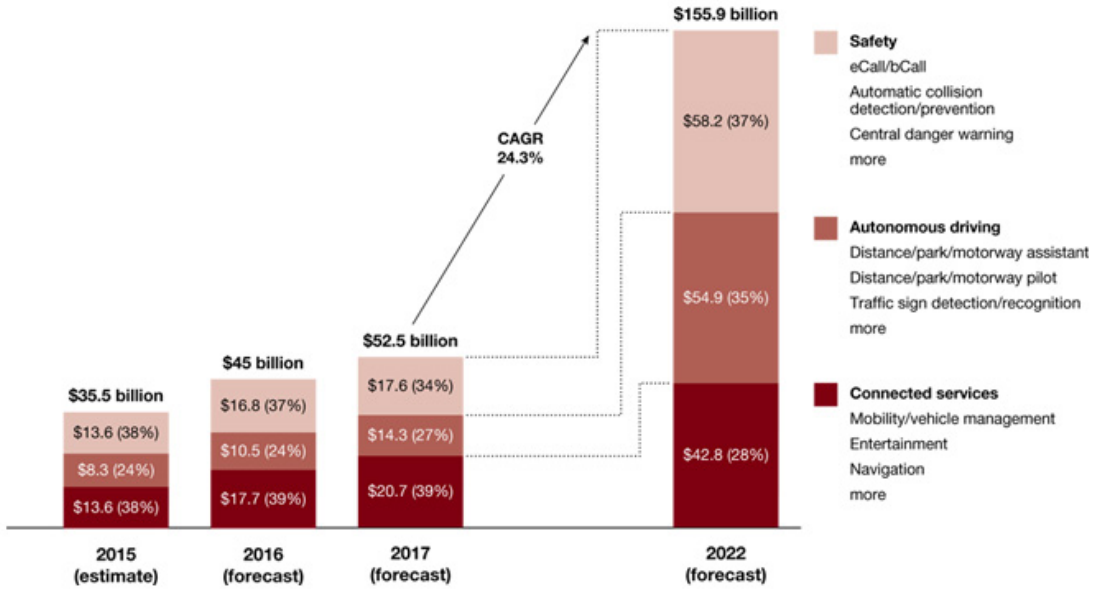
Note: Non-consolidated view: supplier value pools not eliminated from vehicle/aftermarket revenues to show full industry value pools.
Source: IHS; Autofacts; Frost & Sullivan; KPMG; HBR; Bain; McKinsey; NHTSA; Technavio; National Automobile Dealers Association; OEM reports; Capgemini; Thomson Reuters; Gartner; Oxford Economics; Strategy& analysis

Exhibit 7: Connected car revenue potential, by region, 2017–22



Note: Due to rounding, numbers shown here may not add up precisely to the totals provided.
Source: PwC Strategy& analysis

Exhibit 3: Estimated connected car revenues (and market share) by product package, 2015–22



Note: Due to rounding, numbers shown here may not add up precisely to the totals provided.
Source: Strategy& analysis

8. SWOT Analysis:

8.1. Opportunity 1. Satellite based Vehicle-to-Vehicle Communication

Strengths	– Improves the efficiency and effectiveness of vehicles – Provides auto manufacturers with a more efficient way to update software – Connected cars will improve safety and control congestion in cities – Technological advancements likely to impel market growth – Satellite is the ideal technology to take the connected vehicle to the next level – Having the global communications platform of satellites will be a distinct advantage over LTE networks – Broad coverage and global deployment – Stable and secure communications – Cost-efficient – Large amount of data can be transferred at a single time
Weaknesses	– The implementation of V2V communication requires the automotive manufacturers to agree upon standards – Funding – Data privacy/cyber security concerns – Requires a more scalable and high storage capable cloud platform
Opportunities	– Offers a major market opportunity for Space enabled communications companies – Advancement in wireless communication, sharing of information, and growing roadside communication infrastructure are driving the vehicle to vehicle communication market – Around 70% of global automobile data demand to be met by vehicle to vehicle communication systems in the near future. – Increasing concerns regarding safety, increasing usage of automobiles, and traffic congestion systems – Major car manufacturers such as Mercedes-Benz, Volvo, Audi, Toyota, General Motors and others all have developed strategies for connected vehicles
Threats	– The key restraint of the market is high initial cost, which is hampering the growth of V2V systems. – On-going technologies are working on the cost effectiveness of the methods, but the efficiency of this V2V is decreasing slowly, hence it could be one of the key restraints for market growth.

8.2. Opportunity 2. Satellite-Enabled Autonomous Operation

Strengths	– Several government initiatives are already under way to harness the opportunities in this sector – Reduces traffic congestion and speeds up transfer of people and goods – Autonomously-equipped vehicles will improve the safety and well-being of drivers – The UK economy can also benefit by playing a pivotal role in a global industry – There is already a vast level of connectivity and autonomy in vehicles – compared to just a decade ago – The development of a supportive regulatory framework, investment in digital infrastructure and government funding for R&D in this area has been welcomed by the industry – Connected and autonomous vehicles could create an additional 320,000 jobs – in the UK by 2030, 25,000 of which would be in automotive manufacturing – By 2030, connected and autonomous vehicles could save over 2,500 lives – and prevent more than 25,000 serious accidents in the UK alone – The UK has unrivalled strengths in many of the key areas integral to the development of connected and autonomous vehicles: advanced engineering, systems integration, digital technology and software development
Weaknesses	– Key challenge is how to produce a totally reliable communication system for any vehicle at an affordable price
Opportunities	– UK Government plans a new transport law to spur everything from the country's first spaceport to the production of drones, driverless cars and electric vehicles – Nearly every major automobile company is planning to produce autonomous cars by 2021 – The overall economic and social benefit of connected and autonomous – vehicles could be in the region of £51 billion per year by 2030
Threats	– Lack of consumer trust in autonomous vehicles; many consumers are not yet comfortable with the idea of robots controlling the vehicle – Alternative technology such as LIDAR for mapping/GPS

8.3. Opportunity 3. Vehicle to Vehicle Satellite Communications for Automobile and Air Traffic Management

Strengths	– Satellites and it associated ground communications stations are today the most reliable, secure and efficient way of transmitting data and voice between the different components of automobile and air traffic management infrastructure at national or continental level – Efficient datalink services allow traffic and flight plans that can be continuously updated to maintain the best path to the destination – Air traffic control can offer better routings, sequence aircraft far in advance, and maximise airport and airspace capacity – Reduces flight times and airborne holding – Supports continuous descent – Reduces fuel consumption, delays and carbon dioxide emissions – Concrete benefits to airlines and their travellers – reduced flight times, more savings on fuel consumption and even more advanced flight safety – A central network management system allows the user to have a full control of its network – Ability to supervise all events taking place during full-time operations – Reduces traffic congestion on roads and improves safety and efficiency of road transportation
Weaknesses	– Lack of investment
Opportunities	– Majority of vehicle manufacturing companies, such as Audi, BMW, Volvo etc. are implementing traffic control programs
Threats	– Alternative technology such as LIDAR for mapping/GPS

8.4. Opportunity 4. Satellite Broadband to Vehicles: City Infrastructure

Strengths	– Improves the efficiency of monitoring a city's operations and infrastructure – Convenient and user-friendly method for reporting problems in infrastructure – Key to developing concrete solutions for current and future smart-city planning
Weaknesses	–
Opportunities	– Increasing number of "smart cities" in Europe and the UK – Develop more advanced services such as spotting and reporting traffic violations
Threats	– Alternative technology such as LIDAR for mapping/GPS

9. Enablers and Blockers

9.1. Vehicle to Vehicle Communication Market: Enablers

The growth in research and trials of connected vehicles is leading to a point where V2V and autonomous operations will become mainstream within the next decade. Advancements in satellite connectivity and wireless communication, the sharing of information and the growing roadside communication infrastructure is enabling the vehicle to vehicle communication market. Vehicle to vehicle communication has become as active research area due to its potential to improve vehicle and road safety, traffic efficiency, convenience and comfort for passengers as well as drivers. These advancements impact positively on the satellite connectivity and positioning sector.

9.2. Vehicle to Vehicle Communication Market: Constraints

The vehicle to vehicle communication market has many constraints which include the requirement for the automotive manufacturers to agree upon various standards, funding, and data privacy concerns. V2V communication also requires large volumes of data transfer which in turn requires scalable and more storage capable cloud platform. To effectively enable these communications a strong network is mandatory with advanced standards, sophisticated processing, analytical capabilities and technologies. Standardization of protocol, security issues and cyber-attack countermeasures are a few more points which may slow V2V communication advancement.

With the advent and rapid spread of connectivity in vehicles, cyber security has understandably become a major concern within the automotive industry. New connected technologies, including those specifically aimed at increasing safety, have increased the attack surface available to hackers. As vehicles become completely autonomous, they become more reliant on always on connectivity services and GNSS, and even 'driver fall-back' in case of error will no longer be an option. As a result, the risks associated with hacking or GNSS jamming and spoofing will be even greater.

9.3. Challenge for Autonomous Vehicles

Autonomous transport will rely on ubiquitous communications connectivity. Vehicles will need to communicate with other vehicles, transport infrastructures and back office control rooms to know accurately and reliably where they are, where they have been and where they are going to be able to predict both their route and that of other vehicles they may interact with. Vehicle autonomy and connectivity is a wider topic than this, however. Even vehicles that have drivers still need reliable communications to communicate vital sensor and/or positioning information and to send or receive traffic, or location-based service data. This is not only to allow people to get from A to B, but also to enrich that journey.

Similarly, access to accurate timing will be vital for a range of functions, including autonomy. When fully connected, sensors on vehicles can be used for wide variety of purposes, such as alerting emergency services if a vehicle crashes. They offer potential to businesses for tracking goods and vehicles, and can give advance warning of likely events, such as tyre failure, although functions like this will be more valuable when they interact seamlessly with support services.

A key challenge is therefore how to produce a totally reliable communication system for any

vehicle at an affordable price. Every system, whether offering positioning or communications, needs to work anywhere, from built-up urban environments to remote country locations; they need to work in moving vehicles; and they need to be trustworthy, secure against hacking and jamming and resilient to environmental issues such as extreme weather and flooding. They also must be intelligent enough to balance communication costs against signal quality, to make sure all data is reliably transmitted.

9.4. Actions to Take

To realise the potential of the autonomous and connected vehicles market for UK Space companies, it is recommended that the UK space sector develops a coherent and ambitious vision to capture the highest value parts of the value chain. In the case of autonomous and connected vehicles, and potentially for other emerging technologies, this lies in taking steps to own parts of the operating systems that run the new technology.

The following five recommendations which as a package would help UK space companies seize this market opportunity. Companies should do all they can to get in on these areas of development at the earliest possible opportunity:

1. The government should work with business to create the world's first 'real-world lab': an area in a busy UK town where autonomous and connected vehicles and their networks can be used and tested. This could welcome all-comers; once they pass a feasibility stage, and would require that they conform to certain standards to participate (also see 2).

The UK should not just be a playground to test autonomous and connected vehicles without retaining any of the value. The three existing driverless car projects - planned in Greenwich, Bristol and Milton Keynes/ Coventry - could be a useful first phase towards implementing this recommendation. Indeed, a key outcome from these projects could be to clarify the requirements for a real-world lab open to international business: either to identify the best location or to set the parameters for a competition to select one.

An open data platform could be built alongside the 'lab', to ensure that research, experimentation and development takes place within the UK and creates opportunities for international collaboration and partnership. UK Space companies should be an integral part of these establishments, promoting the role of satellite in any applications development.

The UK should act quickly while it retains an international advantage in its regulatory and infrastructure environment. The UK is unique in already having a regulatory system that allows testing of autonomous vehicles on public roads without special permits or surety bonds; the only requirements are insurance and proof that the vehicle is roadworthy. The UK has never ratified the Vienna Convention which requires that "every driver shall at all times be able to control his vehicle". The UK is already home to world-class vehicle testing facilities at Thatcham Research Centre, Millbrook Technology Park and MIRA Technology Park.

The US, Singapore, Germany and Sweden are working to overtake the UK in connected vehicle technological advancement. This summer, Michigan state in the USA is launching a 23-acre mini-

metropolis for vehicle makers to test their cars. Four US states (Michigan, Nevada, Florida and California) already allow autonomous vehicles to be driven on public roads. Singapore is developing a Smart Mobility test bed and Sweden is trialling self-driving cars in Gothenburg for public testing by late 2017. Export opportunities therefore exist for UK Space companies in this area. Contact should be made at the earliest opportunity.

2. The government should identify areas where it can usefully develop standards for key parts of the operating systems for autonomous and connected vehicles. It should work with business, the British Standards Institution and international partners to develop relevant standards and to promote their international adoption. Where appropriate, standards may include related UK-owned intellectual property.

The Government needs to prioritise technologies which meet two criteria: they are fundamental to the sector's future development, and there is a realistic likelihood that the UK might own the relevant property rights. Satellite communications and GNSS positioning systems are two possible examples.UK Space companies must work with the Government to ensure satellite connectivity solutions are an integral part of the thinking and the policy moving forward.

Developing a robust and early set of draft standards will allow the UK to help shape the market and cement its role within it. Embedding globally-filed UK patents within a standard will allow the UK to maintain some control over future versions. Even if the platform eventually becomes an open standard, some economic advantage would remain. This model was implemented successfully by GSM (Global System for Mobile Communications), which became the default global standard for mobile communications in 2014 with over 90% market share.

Two issues need to be addressed as this is taken forward:

- Timeliness. Develop a standard too early and it may impede innovation, too late and others may already have done it.
- Retaining flexibility. While value in the standard can be retained through embedded patents, the inclusion of too many may make it unattractive for others to adopt.

3. The Government, together with UK Space organisations should involve the insurance sector as part of the development of standards. Insurers look to standards to develop policies and assess claims. Standards influence the production of insured products and the environments in which insurers can operate. As standards are developed, the government and other relevant parties need to work with the insurance sector.

4. The Government should prioritise its review of domestic legislation to accommodate autonomous vehicles. The government has already announced that it will review domestic regulations by summer 2017 to accommodate driverless vehicle technology, and a Code of Practice for testing automated vehicle technologies will be published by the Department for Transport this summer. This should also consider the difficult questions around civil and criminal liability. This work forms a crucial component in making the UK an attractive place for companies to test their technology.

5. The government could focus its future research competitions on practical schemes that will enhance the capability and usability of autonomous and connected vehicles.

The government currently plans to run five annual competitions for connected and autonomous vehicle collaborating with others to generate research and development worth a total value of £200m. We suggest that some of this research could focus on the following:

- How best to enhance the capability of autonomous and connected vehicles: for example, creating a system to plan and manage the journeys of autonomous vehicles could help increase capacity and more efficient use of the road network. Similarly, creating a system for differential pricing, depending on the route or time of day for instance, could help spread out demand on the road network.
- Understanding system interdependencies: This should span digital and virtual infrastructure including communications, as well as physical infrastructure like roads, lighting and signals. This work could help identify any gaps in the necessary infrastructure across the country and prepare for contingencies in case of a system failure.

Public acceptance will be crucial to the uptake of autonomous technology and it is essential to understand public attitudes to autonomous vehicles. This issue, amongst others, will be explored in the government's first research and development competition.

10. Market Dynamics

The high cost and long timescales typical of the incumbent space industry are primarily due to the risk adversity associated with satellite development programmes. This has been for good reason; getting a platform to orbit, in particular those at geostationary altitudes, is a costly endeavour and failures cannot be rectified easily. However, innovative approaches to design, exploiting COTS technologies, standardisation of launch vehicle integration and increased availability of piggy-back launches to sub-optimal orbits are enabling greater access to space and new uses for satellite data. This new approach is dependent on an iterative development programme: build, fly, learn, revise and fly again, and one which is heavily reliant upon the satellite industry’s supply chains.

10.1. Vehicle to Vehicle Communication Market: Regional Outlook

A lot of investment is done in experimenting and trying to develop the best vehicle to vehicle communication systems in the US, Japan, and the European regions. North America, majorly the United States, currently dominates the global demand in the vehicle to vehicle communication market. The European market is likely to witness highest growth. With the rise in population, people accepting the technological advancements and increasing number of vehicles in Asia Pacific and Middle East and Africa regions, the potential for vehicle to vehicle communication market is greatest in these areas as more and more automobile companies are focusing on these regions. Latin America should also witness a steady growth in the forecast period.

10.2. Vehicle to Vehicle Communication Market: Competition Landscape

BMW, Audi, Daimler, Volvo, and Ford, (Applink), are included among the automobile manufacturers who are focusing on vehicle to vehicle communication market. Among the solution providers Etrans Systems, Qualcomm Technologies Inc., Cisco Systems Inc., Delphi Automotive PLC, Autotalks Ltd., Denso, Arada Systems, Kapsch Group and Savari Inc., are all active in this sector. UK Space companies would do well to engage with these organisations at the earliest opportunity.

10.3. Global Navigation Satellite System Market

The Global Navigation Satellite System (GNSS) industry plays a vital role in the ability of the countries to determine the position, velocity and local time from satellites in space. Over the past few years, the rapid growth in GNSS commercial applications has been observed by the firms building navigation satellites and equipment. The advancement in technology and increasing interest in positioning techniques based on Global Navigation Satellite Systems, (such as Global Positioning System (GPS) or Galileo), cellular network infrastructure or on the integration of the two technologies for applications such as Automatic Vehicle Location (AVL) tracking systems, has led to development in the navigation system aspirations of various countries such as US, India and China. Backed by such developments and advancement, GNSS market is forecasted to grow at a CAGR of around 10% during 2016-2022.

Growing popularity of IoT and machine to machine (M2M) communication will be one of the major trends in the market. The growth in automotive industry will be one of the major factors that will drive the growth of the market.

GNSS is used around the globe, with 3.6 billion GNSS devices in use in 2014. By 2019, this is forecasted to increase to over 7 billion – for an average of one device per person on the planet. There is an opportunity for space companies to work closely with manufacturers to ensure that connected vehicles utilise GNSS for more than just positional data.

11. Market Trends

11.1. Vehicle-to-Vehicle Communications Market Trends

Market trends in Vehicle-to-Vehicle Satellite Communication include:

- Advancement in wireless communication, sharing of information, and growing roadside communication infrastructure are driving the vehicle to vehicle communication market. Vehicle to vehicle communication has become as active research area due to its potential to improve vehicle and road safety, traffic efficiency, convenience and comfort for passengers as well as drivers, these advancements impact positively to the V2V communication market.

- Shifting trends towards technology safety systems are expected to spur growth in the V2V communications market. For vehicle manufacturers by recent it has been estimated that around 70% of global vehicle output will have embedded vehicle to vehicle communication systems in the near future.

- The process of providing safety to customers and drivers has risen substantially in the past years. Increasing concerns about accidents and increasing usage of vehicle and traffic congestion systems are expected to lead to an increase in stringent regulations. Customer safety remains paramount and will stimulate the demand for applications that also reduce transportation time and reduce fuel usage, (thereby improving the environment).

- Car manufacturers such as Mercedes-Benz, Volvo, Audi, Toyota, General Motors and others all have a "connected strategy"

Audi has recently launched its Audi Connect Generation 2 system in the new MY2017 Audi Q7 and will roll out this new platform across the vehicle line up over the next couple of years. Malhotra says, "the new game in town" is to provide seamless integration with the devices that the customer brings into the vehicle; whether a phone, watch, tablet, etc.

Volvo launched a connected infotainment service in its cars in the fourth quarter of 2013 throughout Europe, and then in the second quarter of 2014 to all models globally. The Sensus Connect service enables the user to have a variety of connected experiences with available in-car apps. The Sensus Connect is available for all Volvo cars and almost 90 percent of its customers go for the connected infotainment solution.

Mercedes now offers several connected services to its customers. For example, an accident recovery service where, after using the Mercedes-Benz emergency call system, the service connects the driver with the Customer Assistance Centre so that further assistance can be given if required to deal with an accident or a broken-down vehicle. There is also a breakdown management application, which provides technical assistance in the event a car experiences mechanical failure. To this end, the GPS position and the condition of the vehicle are transmitted to the Customer Assistance Centre which informs Mercedes-Benz Service of the issue. Alongside this, there is a maintenance management application where the vehicle detects and reports pending maintenance needs and sends the necessary data to the service outlet as the basis for preparing a service quote.

11.2. Autonomous Vehicles Market Trends

- Increasing Government Support –
  UK Government plans a new transport law to spur everything from the country's first spaceport to the production of drones, driverless cars and electric vehicles.

- Automobile Companies Joining Race to Autonomous Vehicles –
  Nearly every major automobile company is planning to produce autonomous cars by 2021, including Audi, BMW, Mercedes-Benz, Bosch, Ford, General Motors, Honda, Hyundai, Jaguar/Land Rover, Nissan/Renault, Volkswagen, Volvo, Tesla and Toyota.

- Semi-Autonomous Vehicles are Already Emerging
  Semi-autonomous vehicles are the stepping stone to fully autonomous vehicles, with most car manufacturers and technology companies taking the lead of Tesla and offering features such as

self-parking, adoptive cruise control, emergency braking and semi- hands-off driving within motorway conditions.

- Europe Joins the Push for Autonomous Vehicles

Momentum is now building for autonomous vehicles, with GNSS as a key component, and here the European Union is delivering the policy support to back up this movement. In April 2016, for example, the transport ministers of all 28 EU Member States signed the 'Amsterdam Declaration' during an informal meeting of the Transport Council. The document lays out the specific steps necessary for the development of self-driving technologies in the EU. With this new Declaration, the European Commission and its Member States, along with the transport industry, have pledged to develop rules and regulations for autonomous vehicles, meaning Europe has a shared strategy on connected and autonomous driving.

This clear commitment on the part of the EU means The European Agency for the global navigation satellite systems (GSA) can move forward with confidence in its support for research in this exciting new area. In fact, several ongoing research projects are already being funded by the GSA under the EU's research framework budget, including Horizon 2020 projects, 'Indrive' and 'Inlane'; many of which involve such European big-name players as TomTom, Fiat or Renault.

In November, a new call for proposals under the Horizon 2020 Framework Programme will be launched. The call will have a total budget of €33 million and is specifically targeting research in support of GNSS, including autonomous vehicle technologies.

The GSA has kicked-off ESCAPE, a three-year and 5.4 M€ project to exploit the services offered by Galileo, the European satellite navigation system, in the field of the automated driving. ESCAPE will coordinate some of the most relevant industrial and research institutions in Europe to create a positioning engine for safety-critical applications on the road, namely, the applications involving highly automated driving.

ESCAPE (European Safety Critical Applications Positioning Engine) is led by the Spanish company FICOSA in collaboration with partners from across Europe: GMV from Spain, Renault and IFSSTAR from France, STMicroelectronics and Istituto Superiore Mario Boella from Italy. All partners are important stakeholders of the value chain in the domain of safety-critical applications for road transportation. By 2019, the ESCAPE consortium will finish the development of an innovative positioning engine tailored to meet the safety requirements expressed by those road transport applications that will involve automation and have the potential to harm or damage people and goods.

The first mass-market GPS and Galileo chipset receiver with multi-frequency capability tailored for the automotive sector is a key element of this innovative positioning device. ESCAPE will enable a high grade of data fusion with different vehicle sensors and the exploitation of key technological differentiators such as the "precise point positioning" service (PPP), the potential use of the Galileo ionospheric model and the provision of an "integrity layer" to assess the degree of trust one can associate to the position information provided by the device. The use of the "integrity layer" is

crucial: in safety-critical applications it is often said to be more important to know whether information is reliable or not than the precise information itself.

ESCAPE will set a new paradigm among and across the technologies enabling road vehicle automation, following the vision of the companies that joined the project. The main keyword of this new paradigm is “safety-oriented” while the pathway is the integration of multiple sources of positioning information (multiple satellite constellations, multiple signal frequencies, and multiple on-board sensors including maps) and high accuracy services.

ESCAPE has been funded under the Fundamental Elements programme of the GSA, a new EU R&D funding mechanism supporting the development of EGNSS-enabled chipsets, receivers and antennas, with the major objectives of facilitating the adoption of the European GNSS Systems and improving the competitiveness of the EU industry, by addressing specific user needs in priority market segments. The UK Space sector must be part of this initiative

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