April 2020

Automotive Safety and Security: A window into innovation through patent data

There are four key trends driving change across the automotive industry and its supply chain. These are loosely categorised as diverse mobility, autonomous driving, electrification, and connectivity. Each of these presents challenges and opportunities for automotive manufacturers, their suppliers and a whole league of new disruptive technology players. There are winners and losers as the industry evolves to meet the demands of consumers along with more stringent environmental & safety standards.

The vision is one that autonomous vehicles (AVs) will effectively reduce road accidents caused by human error. The pitch is that autonomous systems together with real time communications, vehicle to vehicle (V2V), to road infrastructure (V2I) and to pedestrians (V2P), will lead to a material improvement in safety for all road users. Couple that with efficiency gains through enabling a complete transformation in traffic flow management and with how vehicles are monitored and maintained. All of this sounds great, however, the technology advances and shift to autonomous vehicles bring with it a new set of safety and cybersecurity challenges.

Analysing patent data we identify the following:

- Investment in Automotive Safety & Security continues to gather pace
- Significant progress made in Passive Safety Technologies for Pedestrian Protection
- Pedestrian Safety is a material area of investment within Autonomous Vehicle Research
- Millimeter Wave Radar is the leading sensing technology ranking ahead of both Lidar and Radar in patent flings over recent years
- Cyber risk, the vulnerabilities are understood, but there is work to do

Our position here is a simple one. We recognize the role of patents in strategic business intelligence, in providing a view into who owns what technologies and where. By harnessing the latest advances in machine learning combined with expert analysis, information can now be accessed with efficiency, accuracy and at a speed that is just not possible by traditional methods. Using Cipher and an automotive technology taxonomy built across nine high-level categories and extending to over 200 specific technology topics we look at innovation and invention trends across safety and security, against the wider backdrop of automotive industry activity.

Investment in Automotive Safety & Security continues to gather pace

Chart 1: Automotive Technology Categories, Patent families filed 1990 – 2018

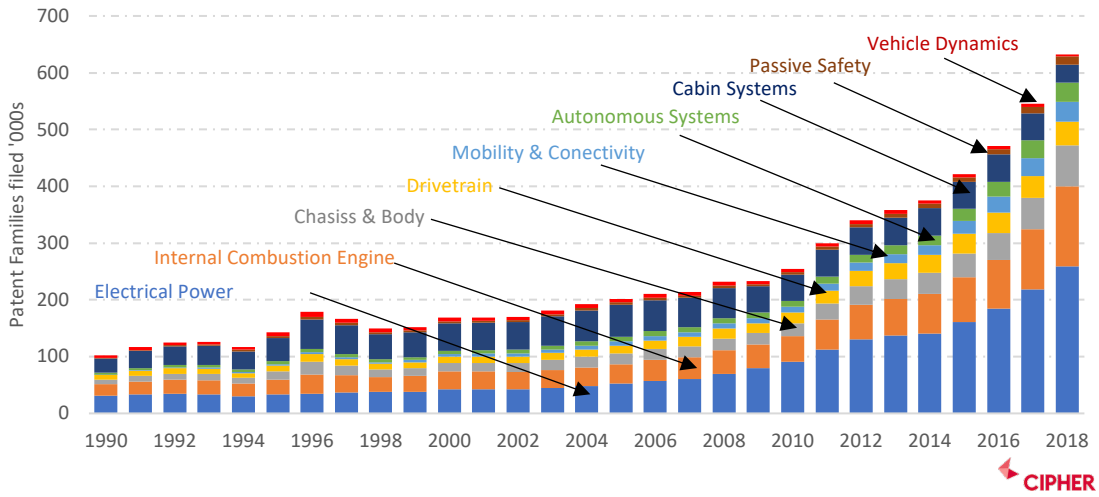
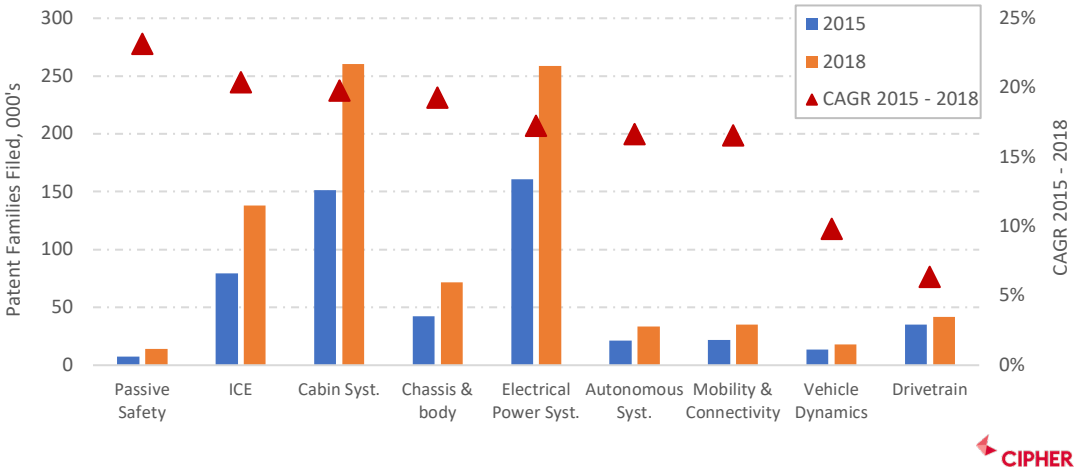


Chart 2: Automotive Technology Categories, Patent families filed 2015 – 2018



Our expectation is for no near-term slowdown in pace with respect to filing trends within Automotive. Across the nine broad technology categories that we have looked at there are a total of 3.3 million active patent families today. Annualising the available data for 2018, the most recent year that data is available, we estimate that combined patents associated with electrical power systems, internal combustion and chassis & body account for three quarters of the total patents filed. Autonomous systems related patents 5% and passive safety related only 2%.

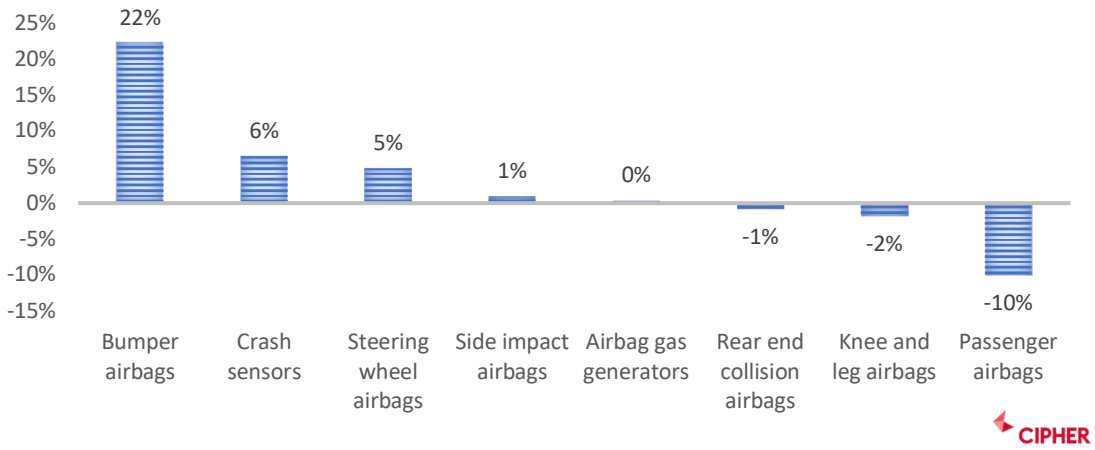
Passive safety is the top ranked technology category by recent filing growth with a 23% compound annual growth rate between 2015 and 2018. Safety systems, non-passive, are of course built into other of the categories included in our taxonomy. For example, within autonomous systems we have anti-collision, auto braking, driver drowsiness sensors and more. We expect the growth trend of safety related filings to continue across both passive and non-passive technologies. Cybersecurity is bundled in within the mobility & connectivity category, but patent filing trends specific to it show a CAGR of 24% between 2015 and 2018.

Significant progress made in Passive Safety Technologies for Pedestrian Protection

Pedestrian protection countermeasures adopted by several car companies in recent years include the addition of external airbags, cameras and sensors to detect when the vehicle is about to hit a pedestrian. In 2012, Volvo cars released the first commercial pedestrian airbag system: the V40 launched in Geneva had seven sensors and an airbag that deploys in the windscreen lifting the hood to protect the pedestrian head from the impact. In 2017, Volvo cars incorporated an inflatable bumper that acts as a cushion for the impact of the vehicle against the pedestrian's legs and airbags that pop out from the bonnet. **Integration of bumper airbags for pedestrian leg protection with liftable hood and windshield airbags can materially reduce pedestrian injuries in the event of a collision.**

Within the broad technology category of passive safety, we include eight specific topics. These are airbags specific to the bumper, steering wheel, rear-end of the vehicle as well as side impact airbags, knee and leg airbags, passenger airbags, gas generators and crash sensors. Looking again at recent growth in filing, bumper airbag technology is the top category within passive safety, with a CAGR in patent filing between 2015 and 2018 of 22%.

Chart 3: Patent families filed by technology, CAGR 2015-2018



Over 45% of total EU road traffic deaths affect car occupants, 21% pedestrians. Collisions between vehicles are the single most frequent category of accidents and one quarter of occupant injuries are the result of side impact collisions (European commission, Vehicle safety 2018). In January 2016, EuroNCAP increased the side impact barrier mass used in crash impact test from 950 kg to 1,300 kg; that same year registered a 30% increase in patent filing activity in side impact airbags.

Analysing the global patent distribution across bumper airbags, we see that Hyundai owns 22% of active patent families in this area, followed by Hyundai Mobis and Ford which each own 6% of the total. Extending the analysis to include active hood and windshield airbag technologies, we have a more representative picture of the patenting activity in the area of passive pedestrian safety systems (Chart 4): Toyota alone owns 13% of active patent families in this area, followed by Autoliv (6%), Hyundai (6%) and Takata (5%). Surprisingly, Chinese auto company Geely, the parent company of Volvo cars, has only 3% of active patent families in exterior airbags. Looking at the geographic distribution (Chart 5), 18% of individual active patent applications have been filed in Germany (this considers applications to the EPO as well).

Chart 4: Active patent families filed in exterior airbags by organisation

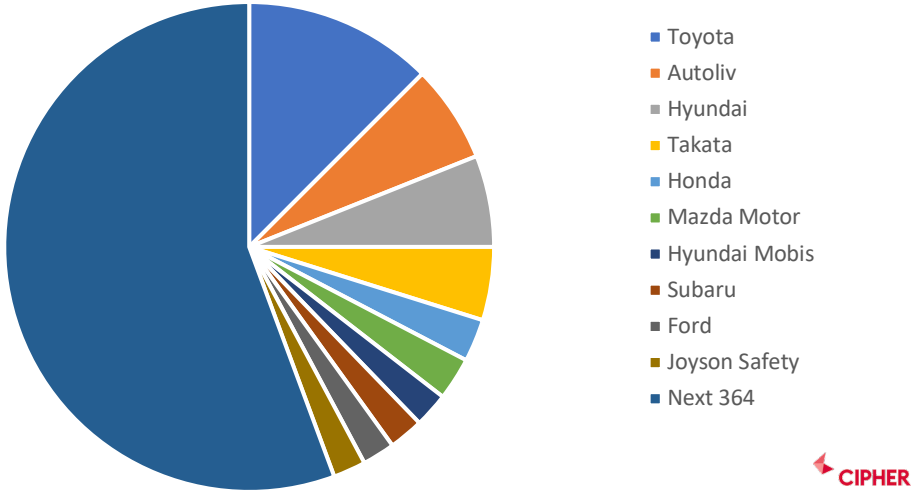
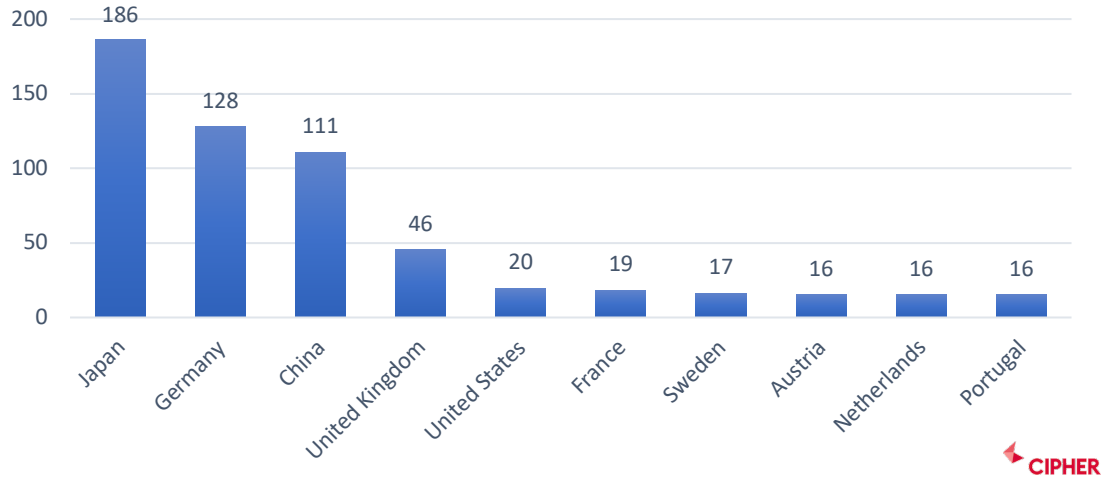


Chart 5: Active patent applications in exterior airbags by top 10 countries filed



Pedestrian Safety is a material area of investment within Autonomous Vehicle Research

Attention to pedestrian safety dominates the ADAS technology area; between 2015 and 2018 filing activity related to pedestrian detection systems increased by 46%. **The technology focuses on sensors to recognise cyclists and pedestrians around the vehicle, for example during parking manoeuvres or intersection**. It is easy to understand the necessity of detection sensors to make airbag systems work or to send warnings to the drivers, but this is about protecting pedestrians.

If we consider AVs, the importance of detection systems becomes crucial. Sensing technology is a defining foundation of AVs (Automated Vehicles and Pedestrian Safety: Exploring the Promise and Limits of Pedestrian Detection, 2019). In fact, any type of reaction starts with the detection of surroundings. Since 2018, 1,135 patent families have been published in pedestrian detection technology with Asian organisations dominating, the Chinese in particular. The University of South China, Mergvii Tech and Tianjin University are the top leaders. Geography distribution of active patent families reflects the predominant position of China (Chart 6). Narrowing the publication analysis down to European and US patents we can see a different picture (Chart 7): Hyundai, Bosch, Valeo, Continental and Halla hold 37% of patent families published since 2018.

Chart 6: Current active patent families in pedestrian detection technology by region

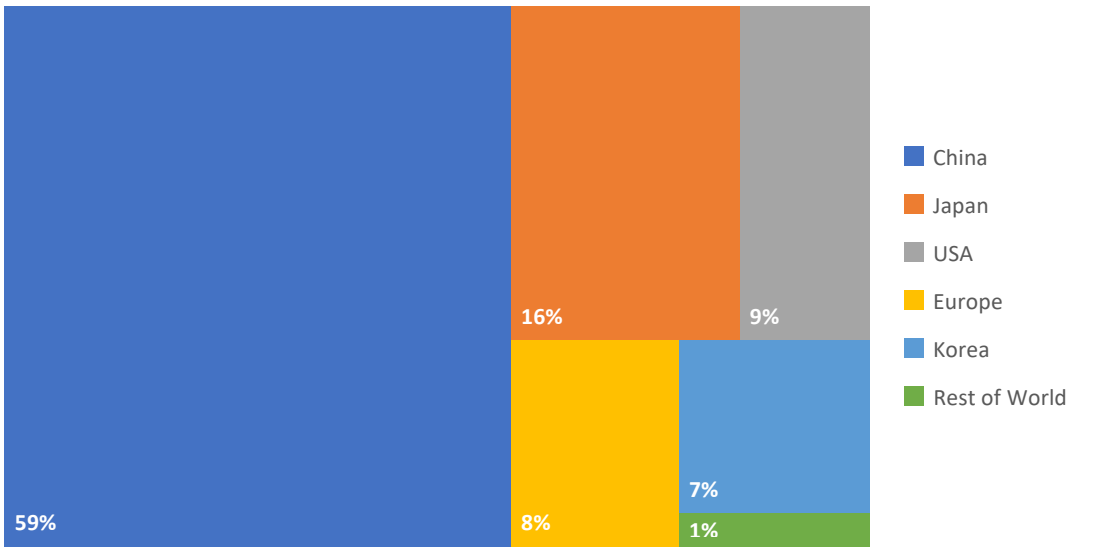
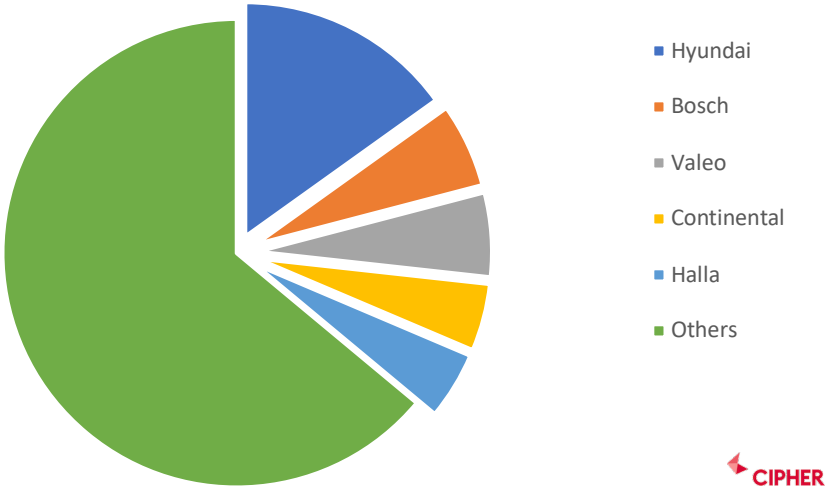


Chart 7: Patent families published since Jan 2018 in the EU and US in pedestrian detection technology



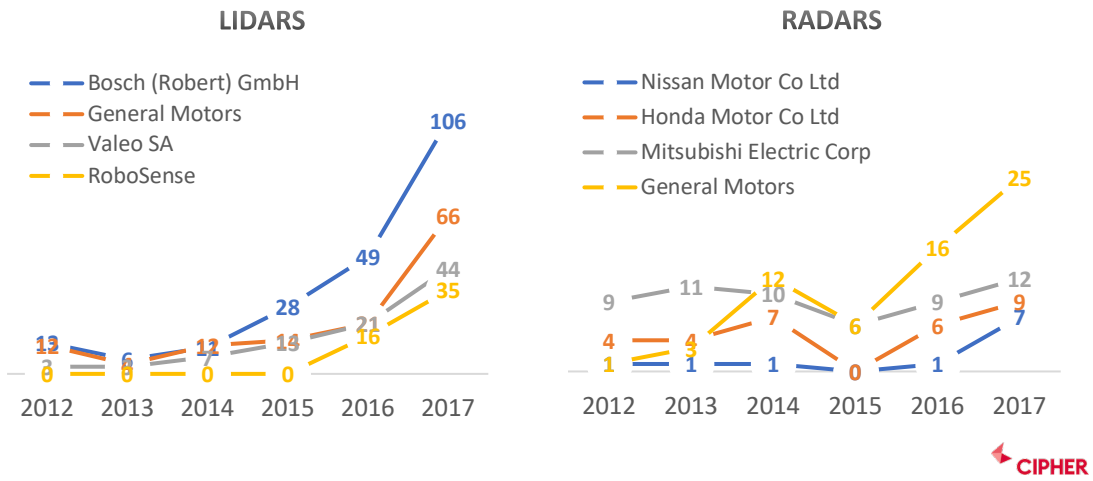
Millimeter Wave Radar is the leading sensing technology ranking ahead of both Lidar and Radar in patent flings over recent years

Achievement of a zero-accident target is only possible with a visualization system that can effectively recognise the environment around the vehicle and, in particular with one that is able to detect objects and pedestrians. Which are the best candidates to accomplish this task?

Lidar (light detection and ranging) and **radar (radio detecting and ranging)** are the two systems most commonly used in self driving vehicles. Technically speaking, radar uses radio waves to detect objects and determine their range, angle, and/or velocity while lidar uses pulsed laser light to analyse the vehicle surroundings. Alphabet owned Waymo uses very advanced lidar sensor technology developed in house to generate high precision 3D images that can even figure out what direction the pedestrian is facing. Tesla's autonomous cars rely instead on radar sensors as primary detection technology. **Lidar sensors are more expensive than radar, they have more moving parts that can generate errors and also, they have limited usage at night time and during bad weather conditions.** Radars are less expense, they work equally well in all-weather conditions and they can provide precise velocity measurements, but shorter wavelength does not allow the detection of small objects.

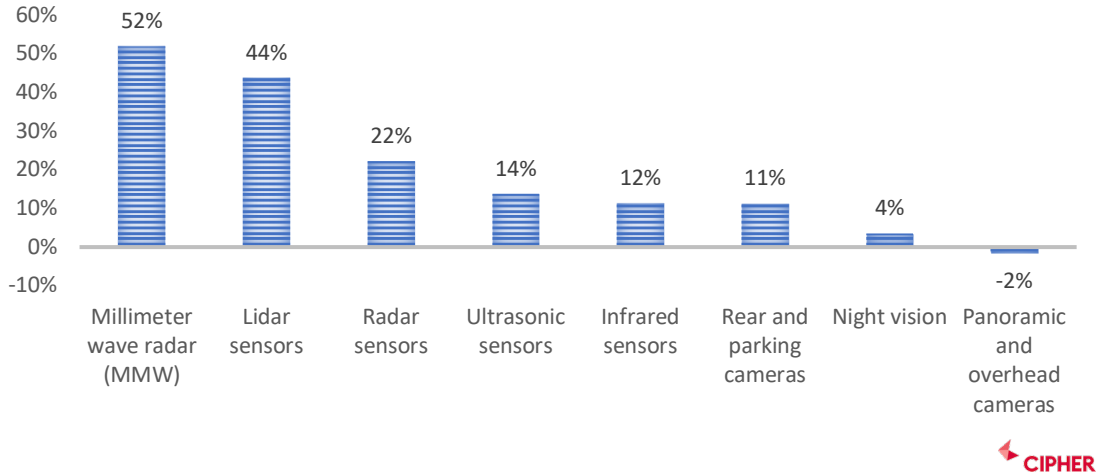
Bosch and Denso are the top companies per active patent families in the area of Lidar and Radar. It is interesting to see the increase in Lidar sensor filing activity by Bosch, GM, Valeo and Chinese start-up RoboSense (Chart 8). There has been an increase by GM in filing activity in Radar sensors as well. Nissan, Honda and Mitsubishi electronic have also raised the number of patents filed in radar sensors over the last years.

Chart 8 and 9: Patent families by priority date and by organisations in Lidars and Radars



Comparing filing CAGR between 2015 and 2018, full-year adjusted, of different sensor technologies used in self-driving applications, **millimeter wave radar (MMW) is the leading sensor technology by patents filed, followed by lidar and radar.**

Chart 10: Patent family filing by sensor technology, CAGR 2015 - 2018



Thanks to their short range (wavelengths from 10 to 1 mm, 77-81 GHz band), MMW radars are able to detect small object with high precision, overcoming the limits of traditional radar technology. **Automotive radar is today's leading sensing technology for improving driving safety in all environmental conditions and MMW radar takes advantage of the higher frequency band for better resolutions, lighter and smaller design. MMW radar technology has been widely used in current advanced driving assistance systems and is also applicable to upcoming AVs.** Example of implementation of advanced radars for self-driving cars is provided by Huawei, who will utilize its 5G technologies to develop millimeter-wave radar and laser radar for AVs applications. It is worth mentioning here weaknesses of MMW technology, which include oversensitivity, limited range, interference.

Focusing our attention on patents active in this technology, our analysis shows that the dominant countries per number of applications and granted patents are China (67%) and Japan (13%), followed by US (9%) and Europe (5%). There is significant patent activity by Chinese universities, especially considering publications over the last few years (Chart 12). If we exclude patents filed only in China, Toyota, Mitsubishi Electric and Infineon Technology are the top three companies per active portfolio size in this technology (Chart 13).

Chart 11: Application and granted patents by country in MMW radars (Top 10 countries)

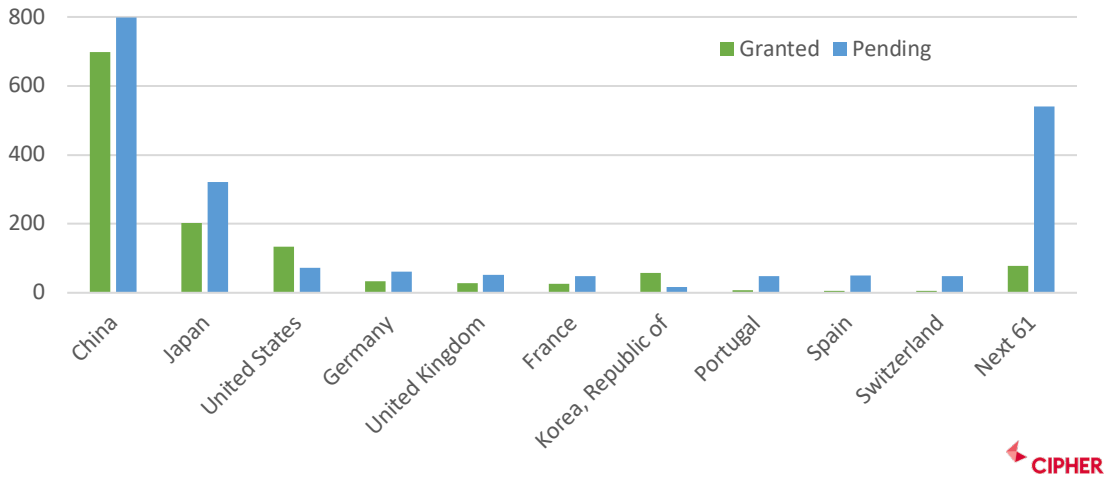


Chart 12: Active patent families published in MMW since Jan 2018

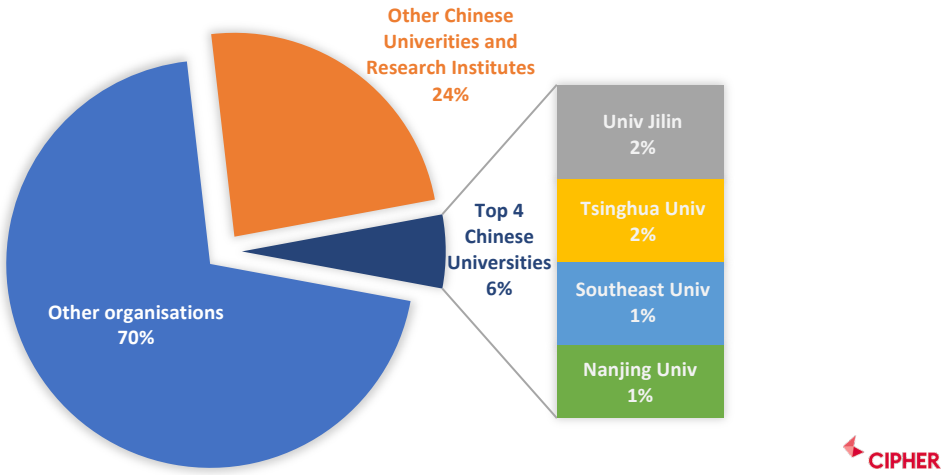
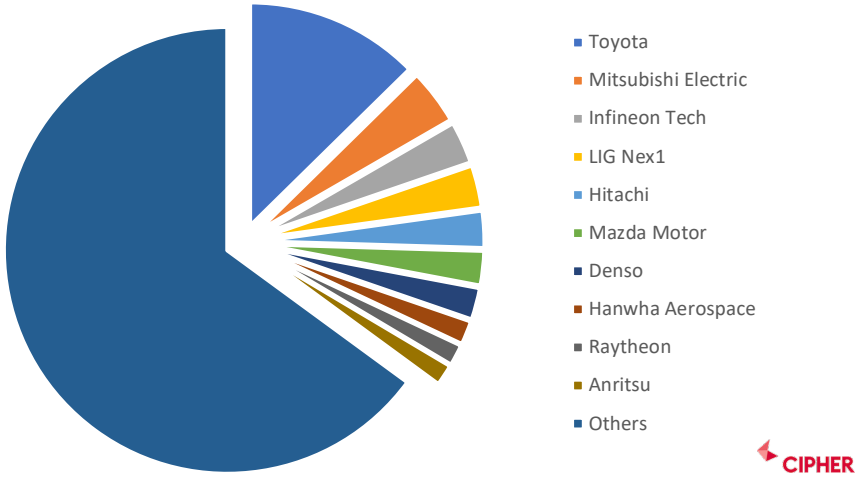


Chart 13: Active families by organisations in MMW radars (excludes families filed only in China)



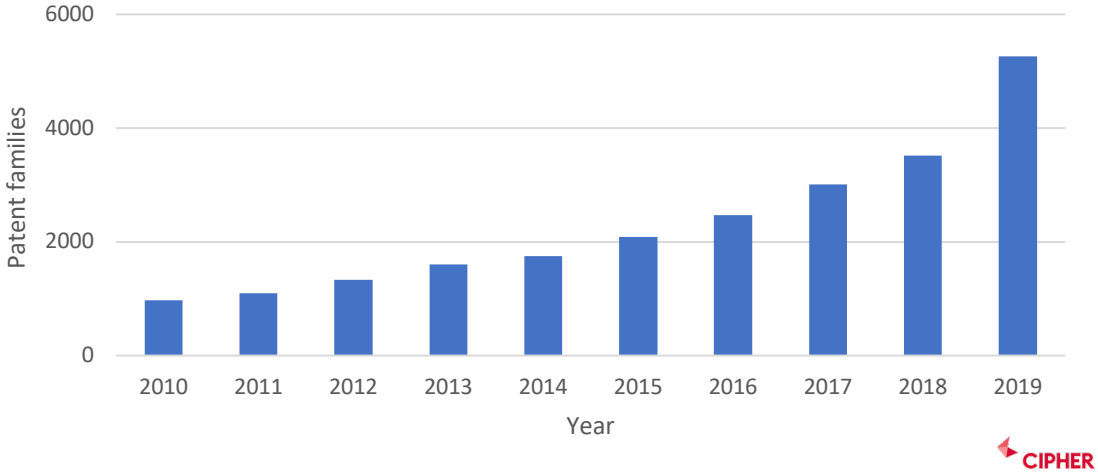
Cyber risk, the vulnerabilities are understood, but there is work to do

Another technology key to reaching the “zero fatalities” target is communication and when safety systems become connected as part of V2X (vehicle to everything), cybersecurity gets critical. In fact, avoiding unauthorised access is essential to guarantee the correct behaviour of AVs and avoid accidents.

According to a survey conducted by Synopsys and SAE International in 2019, 63% of respondents (OEMs and suppliers) said that they test less than half of the hardware, software, and other technologies for vulnerabilities. **There is a significant awareness of the cybersecurity problem in the automotive industry and the need to make improvements.** Patent data helps to understand new inventions and new players in this technology.

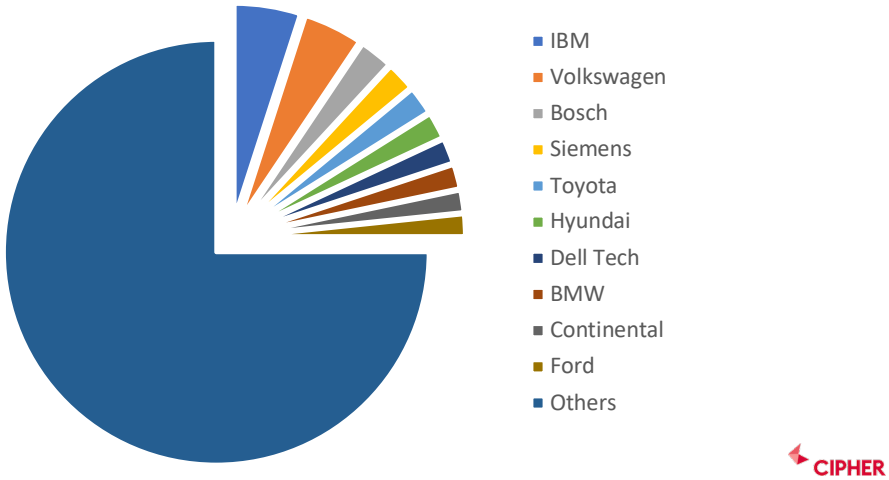
Looking at the patent families published in Cybersecurity over the last 9 years, it is easy to realize that this is a fast-growing technology area, which has seen a massive increase in patenting activity over the recent years, especially between 2018 and 2019.

Chart 14: Patent families published in automotive cybersecurity by year



Narrowing the analysis down to the patent families published since 2018 in EU and US, it is possible to draw a useful picture of the most active players in this technology.

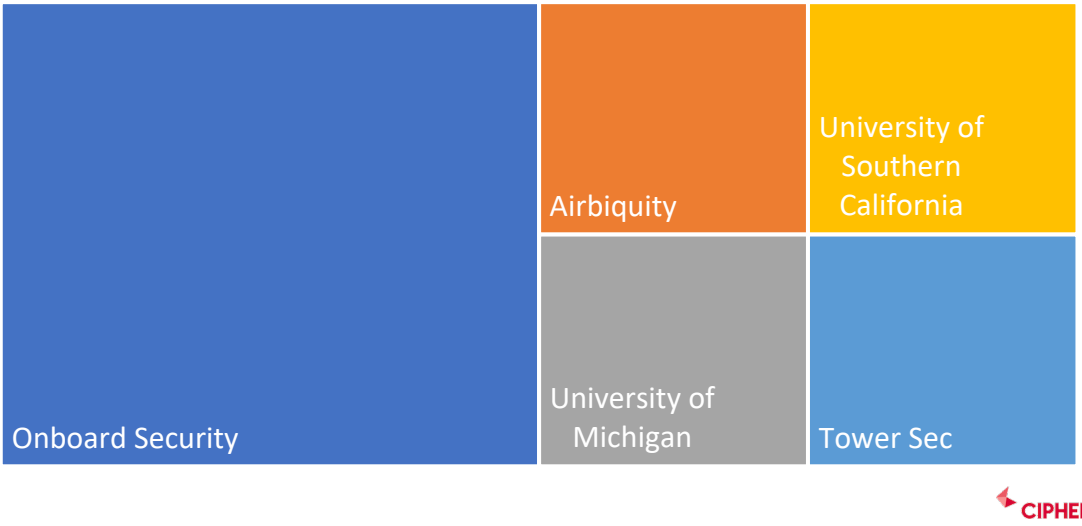
Chart 15: Patent families published since 2018 in EU and US in automotive cybersecurity



Cybersecurity is a relatively new challenge that the automotive industry faces and there is still a way to go in mitigating cyber risk. To develop new solutions and improve their internal capabilities, companies can look for collaborations with Universities or acquisitions of SMEs (small and medium enterprisers) and start-ups.

Cipher, using AI and patents data, has the power to highlight Universities and small companies operating in a particular technology area. As an example, in this case the chart below shows a few of the Universities and small companies that have been active in cybersecurity patent filing in the EU and US over the last 27 months.

Figure 16: Patent families published in automotive cybersecurity for select organisations since Jan 2018, EU and US only



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