



AUTONOMOUS VEHICLES

**HANDING OVER CONTROL: OPPORTUNITIES AND RISKS
FOR INSURANCE**



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1 EXECUTIVE SUMMARY

EXISTING AUTONOMOUS AND UNMANNED TECHNOLOGY IS SOPHISTICATED. IT WILL CONTINUE TO DEVELOP INCREMENTALLY AND BECOME MORE COMMERCIALY AVAILABLE. Autonomous vehicles are vehicles which can drive themselves without human supervision or input. Unmanned vehicles are vehicles which are either controlled remotely, or perhaps operate autonomously. Vehicles can also operate semi-autonomously: taking some control of aspects of their driving, whilst a human driver retains control of others.

AUTONOMOUS AND UNMANNED VEHICLE TECHNOLOGY HAS ALREADY ACHIEVED A HIGH DEGREE OF DEVELOPMENT. Most modern cars incorporate features which allow them to operate semi-autonomously, while unmanned aerial systems are being employed for an increasing range of applications.

THE CONTINUING EVOLUTION OF THIS TECHNOLOGY WILL EXPAND ITS APPLICATION ACROSS A LARGE RANGE OF ACTIVITIES. Autonomous and unmanned technology is emerging gradually but continually, with new opportunities for its employment likely to follow in almost every industry.

WIDESPREAD ADOPTION OF THE TECHNOLOGY WILL RELY ON WELL-DEFINED REGULATORY FRAMEWORKS AND BROAD PUBLIC TRUST ON ISSUES OF SAFETY AND SECURITY. Incorporating autonomous or unmanned vehicles into existing legal and regulatory frameworks will present a major challenge. Additionally, there is significant public concern over safety and responsible use.

AUTONOMOUS CARS INCORPORATE SOPHISTICATED SAFETY FEATURES, BUT HUMAN INPUT WILL CONTINUE TO BE A SIGNIFICANT RISK FACTOR. Notwithstanding the transfer of control, humans will continue to be present in, or have supervision of, autonomous and unmanned cars. Training and education will be required to ensure that people who interact with these vehicles have the appropriate competence and awareness to ensure safe and responsible operation.

UNMANNED AERIAL SYSTEMS (UAS) HAVE A GREAT VARIETY OF APPLICATIONS. INTEGRATING THEM INTO ALREADY CONGESTED AIRSPACE AND ENFORCING SAFETY STANDARDS WILL BE A MAJOR CHALLENGE. With much less requirement for fixed infrastructure compared to cars, UAS offer flexibility and adaptability which enables them to be employed in tasks ranging from aerial surveillance to crop management to parcel delivery. The integration of UAS into airspace regulation is proceeding unevenly, and will serve to slow the development of the UAS market.

INSURANCE HAS A KEY ROLE TO PLAY IN ENABLING THE DEVELOPMENT AND ADOPTION OF THE TECHNOLOGY. Lloyd's provided the first motor insurance policy in 1904, and has a strong tradition of developing new products to match innovations in technology. Insurers will have a significant role in assisting the development of sound risk management practices for autonomous and unmanned vehicles.

LIABILITY WILL BE A KEY CONSIDERATION IN THE DEVELOPMENT OF INSURANCE SOLUTIONS. Autonomous and unmanned vehicles involve a transfer of control from direct human input to automated or remote control. This has implications for the determination of liability in the event of an incident, and will be a key factor in the pricing and structure of risk transfer.

2 INTRODUCTION

Recent headlines have been awash with stories of self-driving cars and futuristic flying devices. Visions of unmanned and autonomous machines are not new, however. Experiments with unmanned aircraft began in the First World War, and a radio controlled car was demonstrated in the streets of New York in 1925.^{1,2} Nevertheless, recent years have seen considerable progress towards the goal of autonomous and unmanned vehicles. Such vehicles are an applied use of increasingly sophisticated artificial intelligence and robotics capabilities. These technological advances are allowing society to fundamentally reconsider the vehicles available to us, and the infrastructure which they are part of. This report looks at two major categories of autonomous and unmanned vehicles: (i) autonomous cars and (ii) unmanned aerial systems (UAS), as well as briefly considering other types of autonomous and unmanned vehicles. The development, as well as the commercial, public and consumer applications of these technologies will be considered, followed by the accompanying risks, and the foreseeable implications for insurers.

The forces behind the development of these technologies are diverse, and represent how traditional transport industries can undergo changes in response to a new generation of machinery. Taking part in the autonomy race, in addition to established car and aircraft manufacturers, are global technological and idea innovators such as Google and Amazon, components manufacturers such as Bosch and Continental, small start-ups and university researchers.³ Their achievements could represent the biggest change to vehicles since the motorcar replaced the horse and cart.⁴

Unmanned vehicles can be defined as vehicles which are controlled remotely by an operator, or autonomously operated. Autonomous vehicles are vehicles which are capable of driving themselves. In order to do this, the vehicle must be able to perceive its environment, make decisions about where is safe and desirable to move, and do so. It can also be possible for a vehicle to be only partially autonomous, so that some decisions are made by a human driver, and some by the machine itself.



Futurama exhibit, 1939 New York World Fair

With new technology comes new risks, and public fear and scepticism about autonomous and unmanned vehicles have not been insignificant.^{5,6} However, motivations for their development include increased safety, efficiency and improvements in quality of life and work. For instance, 93% of road traffic accidents are caused by human error, with 1.3 million fatalities and 50 million injuries every year globally.^{7,8} By replacing the fallible human driver with sufficiently capable technology, it is thought that collision rates will substantially decrease, with significant implications for safety.⁹

Beyond road traffic, autonomous or unmanned technology could be suitable for doing jobs which are “dull, dirty or dangerous” for humans.¹⁰ It has an almost inconceivable scope of applications and implications. Unmanned technology can go to places where people would be unable to, such as inside a volcano plume, or carry out repetitive or time-consuming tasks, for which people struggle to maintain concentration. Unmanned vehicles can also potentially be cheaper than the alternative of employing a team of people and a helicopter for an undertaking.¹¹

The potential for change is great, and yet at the same time this must be balanced against the practicalities of implementation, and the achievement of adequate safety standards to mitigate the new risks that come with new technology. The lengthy considerations that would have to go into reworking laws, systems and infrastructure should not be underestimated, nor should public mistrust of putting lives in the hands of technology.

The insurance industry’s expertise in risk management will be a factor in the adoption of autonomous and unmanned technology. In an area where regulation and safety standards are yet to be developed, insurers can encourage prudent progress by making their own risk assessments and providing policies for responsible operators. There is an opportunity for insurers to engage in the transfer of new risks, making it possible for continued technological innovation. This technological innovation may give rise to new business opportunities, with corresponding opportunities for insurers.

3 AUTONOMOUS CARS

This section looks at what an autonomous car is and how it may come to be commonplace on our roads, as well as the factors that could resist this change. It should be noted that although “cars” are referred to throughout, the same principles apply to similar vehicles such as vans, buses and lorries.

3.1 WHAT IS AN AUTONOMOUS CAR?

One major area of autonomous vehicle development concerns an area where machines have already been used for over a century – the motor car. Cars are so widely used that there is already a coherent system in place to organise their operation, perhaps making it easier to understand the scope of autonomous cars. Road traffic could continue to be ordered in a similar way to current systems, and would be used for similar applications – primarily for transport of people and goods. The idea of transferring control from a human driver to the vehicle itself, however, is a quantum leap which some may struggle to accept.

A fully autonomous car can be defined as a car which is able to perceive its environment, decide what route to take to its destination, and drive it. The development of this could allow significant changes to travel – without the need for human supervision or operation, everyone in the car could be a passenger, or it could even drive with no occupants at all.¹² This could allow productivity and leisure time to be reclaimed from commutes, transport accessibility to be widened for those previously unable to drive, and greater traffic efficiency.¹³ Autonomous cars could have a positive environmental impact. Driving at more consistent speeds, with less accelerating and braking, as well as more efficiently chosen routes could result in lower carbon emissions from driving.¹⁴ The efficiency and aerodynamic advantages of road trains are acknowledged in the [Appendix](#).



Public highway test of the SARTRE road train. Source: SARTRE

Various sectors, including taxis, repair garages and the logistics industry may have new challenges and opportunities to consider. For example, car ownership could decline in favour of a renting model¹⁵, and taxi companies could become owners of rentable car fleets. Lifestyles could be influenced – for example, long commutes might become more common, and suburbs could spread further.¹⁶ Whether for better or worse, autonomous vehicles could bring about profound changes to transport and society.

3.2 IMPLEMENTATION: THE STEPPING STONES TO AUTONOMY

Remaining technological barriers to achieving such a revolution are lower than many may realise, but this does not mean that entirely self-driving cars are expected to become commonplace on our roads in the short, or even medium-term future. Obstacles remain for the full implementation of completely autonomous cars, such as adequate regulation, achieving reliable safety standards, and public resistance to handing over personal safety and responsibility to a machine.¹⁷

Even though large-scale change is likely to be slow and arduous, elements of autonomous technology are due to be introduced into cars in the immediate future. Indeed, incremental steps towards vehicle automation have already been taking place for years.¹⁸ Assisted driving functions such as satellite navigation and cruise control are now well-known, and anti-lock braking systems (ABS), an automatically activated safety mechanism, have been mandatory on new EU passenger cars since 2007. Modern cars contain tens of electronic control units (ECUs), computers which control everything from a car's engine to onboard entertainment systems.¹⁹ "Drive-by-wire" technology, which replaces traditionally mechanical connections with electrical systems (analogous to aviation's "fly-by-wire"), has also become increasingly common.²⁰ Many drivers today are unaware of just how automated their vehicles are.²¹

The trend of automation is expected to continue and through the innovation of new features, everyday cars are likely to progressively move closer to full autonomy. In the [Appendix](#) to this report some features which are currently under development or now available are outlined, which are mostly referred to as Advanced Driver Assistance Systems (ADAS).

	Levels of Autonomy	Existing Examples
1 Driver only	The vehicle is entirely under human control but may have some automated systems.	Cruise control, electronic stability control, anti-lock brakes
2 Driver assistance	The steering and/or acceleration are automated but the driver must control the other functions.	Adaptive cruise control: distance to car in front maintained. Parking assistant: steering is automated, driver controls accelerator and brakes.
3 Partial autonomy	The driver does not control steering or acceleration but is expected to be attentive at all times and take back control instantaneously when required.	Adaptive cruise control with lane keeping. Traffic jam assistance.
4 High autonomy	Vehicles are able to operate autonomously for some portions of the journey. Transfer of control back to the human driver happens with some warning.	Prototype vehicles.
5 Full autonomy	The vehicle is capable of driving unaided for the entire journey with no human intervention – potentially without a human in the car.	None

Table 1: Adapted from Autonomous Road Vehicles - POSTnote 443, September 2013, Dr Chandrika Nath, Parliamentary Office of Science and Technology, Parliamentary Copyright 2013

3.3 COMBINING THESE FEATURES – DIGITISING THE CAR

It is the combination of a number of recently developed ADAS features and the option of networking cars with one another, and with infrastructure, that could move cars closer to being autonomous. The use of both Lane Keeping Assist technology, and Adaptive Cruise Control¹ on motorways, for example, would mean that a driver no longer needs to operate steering or pedals. In the more immediate future, the complexity of road systems means that the autonomous driving of cars is likely to be more viable for certain driving conditions, in particular the motorway, and car parks.²²

As cars become increasingly built around digital systems, there is scope for integration with other technologies too. The use of a smartphone in a self-parking system is described in the [Appendix](#). As the capabilities and boundaries between different forms of electronics blur, there could be a need for common information frameworks.^{23,24} Major computing companies have already made a movement to integrating their systems with cars – last year, Apple announced plans for integrating its mobile operating system, iOS, into cars, and in January 2014, Google announced a partnership with major car manufacturers to develop its Android operating system for cars.²⁵

¹ See [Appendix](#) for an explanation of these terms

3.4 NAVIGATION: AUTONOMOUS CARS 2.0

The ADAS and networking features described in the [Appendix](#) will increase autonomous functionality in cars, but only in certain circumstances, even when combined. The next step towards achieving autonomy would be the developments of autonomous navigation systems.²⁶ This would mean that a car could do more than avoid dangerous situations or maintain a direct route – it could choose the route to a destination, carry it out, and even make alterations based on factors such as traffic conditions. This would require a far more complex awareness of road protocols such as how to behave at traffic lights and junctions, and how and when to change lanes.

Because of the added complexity of these tasks, and the need for an integrated rather than fragmented set of autonomous features, navigation is a functionality which is likely to be added once the ADAS features outlined in the [Appendix](#) have become more widely adopted. This would not only allow for feedback from field testing of sensors and computing systems also needed for autonomous navigation, but would also allow people to become more familiar with autonomous technology and more welcoming of autonomous navigation.

Like ADAS, navigation may also be implemented in stages, or in limited contexts. Current systems being developed, such as the University of Oxford's Robotcar project, can 'learn' routes that a driver has driven, and when they have learnt enough, the car can carry them out itself.²⁷ This has the most potential for use on commonly travelled routes such as people's regular commutes. At a further stage of development and take-up in the future, when cars can ubiquitously navigate themselves in both known and unknown situations, full autonomy may be achieved.

3.5 BARRIERS TO ADOPTION

Although the development of autonomous technologies is rapidly under way, and in many ways they are commercially available, there are also barriers to a shift to autonomous driving.

3.5.1 Cost

At present most ADAS features are not available as standard fittings to a new car, but as part of an optional safety package.²⁸ The extra cost and optionality of this could restrict ADAS feature take-up, although as the technologies become more established, standard fitment is increasing and prices are decreasing.²⁹ Cost is not just a concern for consumers, however. Many manufacturers already have tight profit margins, and making new features part of a standard package may not be appealing. A former General Motors executive has said that while the technology looks inevitable, it may not deliver much value for shareholders.³⁰



3.5.2 Persistence of driven cars

Older cars are not likely to be retrofitted to keep up with modern standards, meaning that the roads, and the laws of the roads, could have to accommodate both autonomous and manually driven cars.³¹ There are also people who enjoy driving in itself – for example, it is estimated that there are more than half a million classic cars in the UK.³² A study conducted by the UK's Automobile Association found that 65% of people liked driving too much to want an autonomous car, although other reports have shown more enthusiasm.^{33,34}

3.5.3 Legal and licensing considerations

Increasing autonomy of cars provokes theoretical considerations of who should be liable in the event of a crash caused by the car itself. At present in the UK at least, primary liability rests with the user of the car, regardless of whether their actions cause the accident or not. If defective technology caused the accident, the user (or their insurer) has to pursue this legally with the manufacturer. In addition, at present drivers are expected to maintain awareness and supervision of their car, even if they are not in control of driving because semi-autonomous features are engaged, for example both Lane Keeping Assist and ACC.

However, it is worth considering a future scenario where autonomy is fully developed and car users could be legally permitted to be distracted from driving, for example to do things like send text messages. This could require fundamental changes to legislation. It would entail a different level of supervision to aircraft, which require highly trained pilots to oversee autopilot activity. If laws are changed such that they no longer require any supervision in cars, a change in liability assignment may also be called for to reflect the fact that users are not expected to have any control over or awareness of the driving.

While a future scenario such as this is unlikely to be realistic for quite some time, it is worth considering that major points of legislation regarding a user's responsibility when in a car may need to be reconsidered. Even in the more immediate future, legal clarification may need to be given over the role of a driver of a semi-autonomous car. As drivers become more like systems supervisors, in some contexts at least, it would be helpful to update rules and guidance to acknowledge this. It should also be remembered that other countries will have different stances on liability, which may more readily find the manufacturer of an autonomous car liable in the event of an accident. There may also be other incidental legal changes, such as establishing standards of data management, and perhaps the need to store data in a 'blackbox' fashion for examination in the event of a collision.

Licensing procedures may also need to change to reflect the changing roles of driver and car. Emphasis may need to be put on training such as in understanding how to move in and out of autonomy modes, and in monitoring and managing systems which conduct driving themselves. Universal interface standards might be needed in order to make this more feasible, and there may be a movement towards governmental licensing of vehicle technologies. In regard to both licensing and manufacturing standards, consideration is likely to be needed regarding driving or transporting cars across international borders, and international agreements may be needed. While, for the immediate future, semi-autonomous cars can proceed in existing legal frameworks, at more advanced levels of technology and takeup, there could be a need for lengthy and complex reassessment of laws and licensing.

“Autonomous driving is not going to be a Big Bang, it's going to be a series of little steps”

Toscan Bennett, Volvo

3.6 THE FUTURE FOR AUTONOMOUS CARS

Over the next five to ten years, ADAS add-ons such as the ones described in the [Appendix](#) are likely to become more standard, and people are likely to become more familiar with their capabilities. AEB in particular may become a widespread feature, either by mandate, or as a de facto requirement to be seen as a competitive market option. Drivers are likely to become accustomed to semi-autonomous driving, particularly in certain conditions such as stop-start traffic jams or flowing motorway traffic. Cars are expected to become increasingly digitised, and their computerised functions are likely to be better integrated, with a view to developing fully autonomous capabilities.

Industry predictions for autonomous cars range from the near-future of 2020, to a more cautious second half of the twenty-first century.³⁵ Although driving is likely to become ever more automated, it may still take a long time for it to be feasible that all journeys can be driven autonomously. The development of autonomous navigation systems will be significant in moving towards this goal, but it may also take time for developers to achieve adequate safety standards, widespread user adoption, and institutions to adapt frameworks such as legal and licensing procedures to accommodate a whole new generation of technology. It is hard to predict how long these things could take, and they may take time, but autonomous driving is likely to become progressively more advanced and commonplace.

4 UNMANNED AIRCRAFT SYSTEMS (UAS)

One of the most interesting areas of autonomous and unmanned vehicle technology, and with the greatest potential for growth in coming years, is Unmanned Aircraft Systems (UAS).³⁶ The scope of these is far broader than for cars, as they are not bound in the same way by existing infrastructure. The flight paths of UAS are not restricted like cars are to roads, and likewise their size, specification and purposes are limited almost only by the extent of the developer's imagination. Compared to autonomous cars, there are more varied ways in which UAS are built and used, making it harder to identify a development path following the addition of specific features. In order to understand the scope of upcoming UAS availability, their potential applications can be considered instead. To some UAS may seem like a futuristic and perhaps even unrealistic prospect, but it should be noted that, in Japan for example, they have been used commercially for years.³⁷

Many terms exist for this sort of unmanned flying technology, including Unmanned Aerial Vehicles (UAV), and the more colloquial "drones". The usage of the word "drone" in connection with civil (commercial and personal) use of the technology has been consciously avoided by many, as it is widely regarded to have pejorative connotations stemming from the use of similar technology in military air strikes.³⁸ UAV has also been overlooked in favour of UAS, as the latter emphasises the ground support that accompanies unmanned aerial vehicles.³⁹ At this stage in the lifespan of UAS, commercial availability of autonomy is a more distant goal than for cars,⁴⁰ because of the logistical challenges of operating in more varied circumstances than cars. In the same way that a human driver would still be required to oversee the (semi) autonomous operation of a car for the foreseeable future, a remote operator or team of operators is likely to remain a requirement for the operation of airborne vehicles. The term UAS is preferred as a reminder that although these vehicles are unmanned, they still rely, to some extent at least, on ground-based operators.

4.1 APPLICATIONS

The applications of UAS are vast, and span the commercial, consumer, research and public sectors. Below is a list of examples of where UAS can be, and in many cases already are, employed.

4.1.1 Agriculture

Agriculture is a promising area of application for commercial UAS. The Association for Unmanned Vehicle Systems International (AUVSI) has estimated that agriculture will be the primary civil use of UAS, and that around 90% of the UAS market will come from the combination of agricultural and public safety applications.^{41,42} Some countries are already using this technology in the agriculture sector, for example Brazil and Japan.⁴³ A UAS can assist farmers in a number of ways. Their ability to cover large distances makes them suitable for monitoring conditions such as irrigation or frost, or crops and livestock, for example to check for diseases.⁴⁴ They can be used as part of a precision agriculture system, through both surveillance capabilities, and the ability to apply pesticides or fertilisers in targeted areas.⁴⁵ With more extensive development, it is feasible that UAS could also plant and harvest crops, or be used in pollination.⁴⁶ UAS can replace more laborious methods of farming as well as provide improved levels of monitoring, making them an instrument of agricultural modernisation. They can also be cost effective for farmers, as decisions can be made based on better information, and cultivation can be more finely tuned. They can also be much cheaper than alternatives such as manned helicopters.⁴⁷

UAS have great potential for use in agriculture not only for their versatile capabilities, but also because they are less of a privacy and safety risk in rural settings. To perform their functions they would fly at relatively low levels, avoiding the risk of colliding with other air traffic. Operating over large farms also mitigates the risk of causing injury should they fall from the sky or fly too low, and rural areas pose less of a concern of a UAS intruding on neighbours' privacy.⁴⁸ Agricultural UAS would only need to be flown above land owned by the operator, reducing legal and privacy-related contentions.



4.1.2 Public Services

The second biggest use of UAS projected by AUVSI is in public services.⁴⁹ UAS can be useful in assisting with emergency services type undertakings, such as search and rescue.⁵⁰ A UAS' ability to reach inaccessible or dangerous locations, fitted with equipment such as video and infrared cameras, make them useful for tasks such as locating stranded victims of a natural disaster, or missing hill-walkers. They can similarly be used to assist police for locating crime suspects, and for border control monitoring. Small UAS may also reach narrow or awkward locations which helicopters would be prevented from approaching. UAS have an advantage over manned helicopters for locating people in dangerous areas because there is no risk to an onboard crew. For example, UAS can be used in monitoring and fighting forest fires, or can fly in dangerous weather conditions without posing an additional risk to human life.

The Police Service of Northern Ireland (PSNI) used a small remotely controlled UAS in November 2013 to help in the disposal of a bomb in Belfast. The UAS was used to fly over the device to carry out an aerial inspection, sending images back to bomb disposal officers to assist in its diffusion. The UAS was originally acquired by the PSNI for use during the G8 summit in Belfast earlier that year. It was used for aerial monitoring of the venue used as part of security measures.⁵¹

4.1.3 Aerial Surveillance (other)

Both of the above uses of UAS incorporate aerial surveillance, and there are other ways in which the aerial surveillance capabilities of UAS can be used. They have recently been used by estate agents to create marketing videos of high-end properties, and by environmentalists to find whaling vessels.^{52, 53} There has been interest expressed in using UAS for monitoring oil and gas pipelines – the first commercial UAS flight in US airspace which took place in September 2013 was carried out by oil and gas group ConocoPhillips.⁵⁴ UAS can also be used for purposes as various as mapping, patrolling game reserves, and monitoring piracy-prone areas.

Although UAS offer great potential in the field of aerial surveillance, there are also considerable privacy concerns associated with this. In the US, some cities have set limits on the use of consumer drones, and some cities have banned them altogether.^{55, 56} 42 states considered bills restricting the use of drones in 2013, looking at both restricting data gathering activities in law enforcement, and the rights of private UAS users.⁵⁷ Surveys have suggested that there is great public suspicion regarding the privacy implications of UAS.⁵⁸ Concerns about privacy are likely to be one of the biggest sources of resistance to UAS, especially in urban areas.

4.1.4 Media

UAS can be used to record footage that a cameraman would not be able to. For example, they can film both a close up of an object and then fly back for a long-range view, or they can track and follow a moving object such as a running animal. The BBC's Global Video Unit has recently acquired a UAS, and the first reporter to use it said "The pictures speak for themselves . . . it will transform television and online news."⁵⁹ Across the media sector, UAS are already in use for filming sports events, such as skiing, mountain biking and surfing, which are difficult to capture from the ground.⁶⁰ They have been used to make Hollywood films,

including Skyfall, The Hunger Games and Iron Man 3.⁶¹ UAS could be used by paparazzi for pictures of celebrities and other notable persons. This is likely to cause serious concern about privacy rights, which are already a contentious issue in this area.

4.1.5 Delivery

The recent announcement that Amazon was testing UAS for parcel deliveries was met with fervid media coverage and comment.⁶² Several other companies have similarly been experimenting with using UAS for delivery. Among others, Domino's has tested them for pizza delivery, and a drycleaners have delivered fresh laundry by UAS.⁶³ At a music festival in South Africa in 2013, crowd members were able to order beer through a smartphone app, which was then delivered to their location in the crowd by UAS, greeted by "a crowd of 5,000 cheers".⁶⁴

This application of UAS is one which most captures the imagination, but is however problematic for logistical reasons. To have numerous delivery vehicles flying in the sky would necessitate advanced systems to ensure that they did not crash into other airborne objects, or cause damage or injury by falling to the ground. It is not inconceivable that such solutions can be found, but most agree that Amazon's suggestion of a four or five year deadline for delivery UAS is highly unlikely.⁶⁵ Nevertheless, UAS are being used to transport items in some contexts. It has been suggested that although they are currently unsuitable for dense, inhabited areas such as cities, delivery by UAS can be more immediately suitable for use in rural, poorly supplied regions. Airware, a UAS development company, the Massachusetts Institute of Technology and the Bill and Melinda Gates Foundation are working on a pilot project to deliver medicines and vaccines by UAS to remote regions of Africa later this year.⁶⁶

There have been some suggestions for the systematic adoption of UAS for deliveries. AirHighway is a US group of UAS engineers and entrepreneurs which is proposing the creation of aerial 'highways' – dedicated airspace corridors – for use by fully automated UAS. They propose that these would navigate by sensors, be able to replace their own batteries, and identify and deliver packages using identification tags.⁶⁷ While delivery by UAS may one day revolutionise shipping, the need for extremely high safety standards, infrastructure investment, and meticulous integration planning mean that this is unlikely in the near future.



Airspace highways. Source: Matternet, Inc.

4.1.6 Other uses

UAS can come in almost any conceivable size and design, and accordingly there is a wide scope for how they can be applied by entrepreneurial developers. Some other uses of UAS which have been suggested include for advertising, and flying solar power farms. UAS can make useful research tools, for example NASA has used them for taking measurements such as the air temperature, humidity and pressure of hurricanes.⁶⁸ Beyond the commercial and research sectors, there is also interest in UAS from private

hobbyists. The versatile capabilities of UAS mean that they can be designed for numerous different purposes, and this is likely to lead to a substantial business market.

4.2 LEGALITY AND REGULATION

The regulation of UAS differs from country to country, as national airspace regulation and privacy laws vary. Some countries, such as Australia, have more tolerant regulation, but many countries currently exercise tight restrictions over their operation.⁶⁹ For UAS to become commercially viable, laws and regulation may need to be overhauled, and this could take time. At present many countries impose restrictions such as always having a human operator in control, flying in line-of-sight of a ground operator, or flying within limits such as the UK's restriction that UAS can fly no higher than 400ft.⁷⁰ Permission to exceed normal restrictions may be granted to an operator that seeks special permission, or arrangements may be in place for testing and research. In recognition of the fact that UAS can vary considerably in terms of size and scope, they are typically banded into different weight categories, with different regulations for each category.

Some countries have already taken steps towards issuing comprehensive new guidance for UAS, and other countries have expressed their intention to follow suit. For example, in December 2013 the USA's Federal Aviation Authority (FAA) outlined sites in six states which it has designated for commercial testing of UAS. As well as testing for technical and safety development, the research aims of these sites include a focus on airspace procedure and certification standards.⁷¹ As researching and testing continues throughout the world, national as well as international aviation laws and conventions may need amending to take UAS into account.

Rethinking legislation and regulation to suit commercial applications of UAS is a difficult task which requires consideration of safety and privacy. Countries which are early in accommodating UAS, however, could be advantageously positioned for a large market that is waiting to develop.⁷² The Association for Unmanned Vehicle Systems International (AUVSI) has estimated that integrating UAS into US airspace would have an economic effect worth more than \$13.6 billion, and create more than 70,000 jobs in the first three years, and by 2025 this could reach \$82 billion and 100,000 jobs.⁷³

4.3 OUTLOOK FOR UAS DEVELOPMENT AND ADOPTION

The path that UAS undergo towards being everyday technology is not likely to be as uniform or predictable as for autonomous cars, given the variety of size and capabilities that different systems have, and the fact that they operate with less constricted physical infrastructure. There are a wide range of commercial uses for UAS, and big potential for this market to expand. The main barrier to uptake is the lack of provision for UAS in laws and airspace protocol, and it may be a time-consuming task for countries to establish suitable frameworks for UAS to safely operate. Nevertheless, many countries have expressed commitment to achieving this task, and recent years have seen increasing progress towards the opening up of the skies for commercial UAS.



Source: National Museum of the US Air Force.

5 OTHER AUTONOMOUS AND UNMANNED VEHICLES

The possibilities of robotics and communication technology mean that autonomous and unmanned vehicles do not just exist on public roads and in the air – there are almost limitless ways in which they can be designed and applied. Below are some other potential expressions of autonomous and unmanned vehicles.

5.1 MARINE

Autonomous and unmanned technology can be used in marine settings, both in underwater and surface vessels. Scientific research is a main area where these can be used, such as for mapping ocean features like coral reefs.⁷⁴ Another area of use is in observation of the sea for commercial reasons, such as in the oil and gas industry. Research to develop autonomous, unmanned cargo ships is in progress.⁷⁵ It has been suggested that autonomous submarines could be used to search for illegal drug smuggling submarines, which are increasingly common.⁷⁶



Crewless ship concept. Source: Rolls-Royce.

5.2 SPACECRAFT

Autonomous technology has been used in spacecraft for decades. As with other vehicles, spacecraft can have autonomous technology for a variety of functions, which may control the whole spacecraft's operation, or work in conjunction with a human operator. Applications where autonomous technology is used or under development include Mars exploration rovers, lunar probes, and supply ships going to space stations.^{77,78,79} Further development of autonomous technology for spacecraft will continue to be a priority for the future in order to extend the capabilities of space and planetary exploration.⁸⁰

5.3 SPECIALISED INDUSTRY USAGE

Autonomous and unmanned vehicles can be used for specific industry applications such as for use in factories and warehouses. For example, a major mining company uses tens of automated lorries to haul iron ore, as well as autonomous trains, on several of its sites.⁸¹ Robots with mechanical arms have been designed which can recognise objects and sense how much force they are exerting on them, allowing them to decide the best way to assemble and transport goods.⁸²

5.4 TRAINS

Self-driving trains have been in use on metro systems since the 1960s, and can now be found in cities all around the world.⁸³ Many have a driver or guard on board to operate some functions, or as a safety precaution, but metro systems are increasingly being run without any onboard staff.⁸⁴ The use of autonomous technology has not had the same take-up in overground, cross-country trains, as these operate in less controlled settings and travel at faster speeds. Accordingly, it would be easier for a pedestrian or obstacle to stray onto train tracks, and much more powerful sensors for detecting obstacles would be needed in order for an adequate stopping distance to be achieved. This could be an area of development for the future, however.⁸⁵

5.5 MILITARY USAGE

A major use of autonomous and unmanned aerial technology has been in military contexts. Indeed, military interest has driven much of the research into UAS which has enabled commercial use.⁸⁶ Military UAS are used for a number of purposes, including intelligence gathering, reconnaissance, and inspecting IEDs.⁸⁷ They are also used for armed strikes, which has attracted a lot of ethical controversy, particularly in the face of civilian casualties.⁸⁸ Military research into UAS has been a key driver in their development but it has also contributed to public fear and scepticism which poses a barrier to adoption of commercial UAS.

6 RISKS

Having looked at the capabilities, applications and regulation of autonomous and unmanned vehicles, this section considers the risks which they present, in order to understand the implications these new technologies have for the insurance industry.

6.1 AUTONOMOUS CARS

Some of the risks associated with autonomous cars are similar to those of traditional cars, however, the nature of these risks will be different. A major factor for the future of autonomous cars will be appropriately evaluating and mitigating these risks.

6.1.1 Transferring risk from the driver to the machine

A major argument for the introduction of autonomous features in cars is that they make driving safer. The vast majority of accidents are caused by human error, and in theory by replacing human input with well-programmed computers, the risks of driving could be substantially reduced.⁸⁹ With less reliance on a human driver's input, however, increased risk would be associated with the car technology itself. Computers can do many things that a human driver cannot: they can see in fog and the dark, and are not susceptible to fatigue or distraction. However, they can also fail, and systems are only as good as their designers and programmers. With an increased complexity of hardware and software used in cars, there will also be more that can go wrong.

The major risk of a malfunctioning autonomous car is the same as for traditional cars – the risk of collision. As with traditional cars, a collision can cause injury or death to both occupants of cars and bystanders, as well as damage to property. The severity of an accident can therefore be very high. For this to be acceptable, care needs to be taken to make sure that the frequency of collisions is extremely low. Extensive and meticulous testing is essential, as is redundancy in systems so that if something fails, there are back-ups in place which allow the continued safe operation of the vehicle. Consideration will need to be given to how well the car performs in a wide range of driving conditions – such as in different weather and road conditions, and on different types of road design.



It is possible that the types of car crash that could occur from the failure of autonomous technology would be of a more severe and less regular character than those caused by human error. While severe accidents can also be caused by human error, it is rare that drivers do something blatantly in contravention of road safety, such as drive the wrong way down a motorway. A computer miscalculation or a faulty reading from a sensor could lead a car to do something that a human driver would instinctively realise is inappropriate. This could potentially lead to unusual and more complicated types of accidents which are hard to predict the nature of.

6.1.2 Residual driver error

In the nearer future the likely scenario is that cars are semi-autonomous and people alternate between driving as usual and switching to a more autonomous mode, or are in control of some driving functions, but not all. By gradually transferring responsibility from the driver to the car, there is a risk that a driver could misjudge the responsibility they currently have, or may not adequately understand how to choose different modes of operation of their car.⁹⁰ To mitigate this risk it is important that drivers are well-educated about the limitations of autonomous functions, and how they can retake control of the car when it is necessary.

This may be a more difficult risk to address than it seems – anecdotal evidence suggests that people have a tendency to 'switch off' when it seems that their input is not needed. For example, it is not uncommon to

hear stories of people who follow satellite navigation instructions that common sense would discredit.⁹¹ Not only can technology make mistakes by itself, it can be used incorrectly, and drivers can be surprisingly accepting of glaring errors. If drivers are expected by law to supervise an autonomously operating car, they may find it difficult to remain focused on this task if they feel able to trust the car. There have been some safety developments to address lack of concentration. Systems which monitor a driver's alertness are under development, as are systems which give a warning message, or provide a haptic response, such as vibrations through the seat when they detect that a driver is tired.⁹² However, as semi-autonomous technology becomes more common, the risk of a driver not paying attention when they ought to could be increased.

6.1.3 Reputational Risk

Because the failure of an autonomous car has serious implications for human safety, there could be serious reputational risk for the manufacturer of a car or component if it is involved in an accident. This is also the case for the manufacturing of traditional cars – even the suggestion of a fault can affect reputation⁹³ – but as technology comes to have a larger responsibility for driving, the risk will also increase. The emotional implications of handing over personal safety and responsibility to a machine could lead to volatile public responses to a fault. People are more likely to take issue with a car and its manufacturer if it crashes itself, than if they had crashed it themselves.

6.1.4 Cyber Risk

As driving becomes more computerised, there is likely to be increased cyber risk. This is a risk that is ever-growing in our increasingly digitising society, but maliciously interfering with a car could have serious implications for safety. To address cyber risks, high standards of system resilience, such as robust data encryption, will need to be engineered.⁹⁴ Consideration will probably also have to be given to how networking with other cars, infrastructure, and personal computers such as smartphones could impact the cyber security of a car.

Cars are likely to deal in large amounts of data, and may be increasingly connected with existing technology such as smartphones and tablets. Through connectivity with other personal digital technology, as well as other cars and infrastructure, there could be potential for unwanted third parties to access data. Although cars already have computerised units, at present they tend to be isolated, not networked, and therefore at less risk. As cars become more connected, it could be possible for hackers to access personal data, such as typical journeys, or where a person is at a particular time, which could for example allow a burglar to know when a householder is not at home. It is also feasible that driving could be maliciously interfered with, causing a physical danger to passengers. There is potential for cyber terrorism too – for example, a large-scale immobilisation of cars on public roads could throw a country into chaos.

6.2 UAS

As with autonomous cars, many of the risks that UAS pose are similar to manned aviation risks, but they have different characteristics and prominence.

6.2.1 Collision

The primary risk is also of collision – with people or property on the ground, with manned aircraft, or with each other. In one sense, UAS pose less of a risk to life than traditional aircraft if they crash, because they do not carry passengers or crew. There is still, however, risk of injury to people on the ground, should a UAS fall out of the sky, and risk to manned aircraft. This will be an increased concern if there are a very large number of UAS operating, and if they operate over built-up areas and at low heights, or around manned aircraft. To mitigate this risk, it is important that UAS are held to the same standards of safety and regulation as traditional aircraft. This may be more challenging if a large commercial UAS market evolves and there are many more aircraft in the skies than before, but it is essential that rigorous safety standards are sought, as with manned aircraft. Furthermore, the remote piloting of UAS would require different skills and allow different situation awareness compared to piloting an aircraft from its cockpit. As with autonomous vehicles, it may be necessary for particular training for UAS operators, to understand the limitations and possibilities of their operation.

There are typical restrictions currently in place on UAS operation to mitigate this risk, such as that they must be flown in line-of-sight of the operator. However, for UAS to become commercially viable equipment, they

must be able to fly with greater freedom, but with reduced risk of crashing. In order for this to happen, adequate safety features, such as Sense and Avoid² capabilities, need to be developed. They would have to be developed to a particularly high standard, on account of the big variation in size of air traffic. For a small UAS to be able safely to detect an oncoming passenger jet and move safely out of its flight path, for example, it would need to have powerful sensors, in order to avoid a much faster flying aircraft. The development of highly reliable Sense and Avoid capabilities would allow more autonomous operation of UAS.

6.2.2 Loss of data link to controller

As such, commercially available UAS are usually operated via a remote operator on the ground at present.⁹⁵ This requires a resilient two-way data communications link between the vehicle and the operator. There is a risk that if this link was lost or disrupted, the aircraft would be out of control. To mitigate this risk, attention needs to be paid to the security and strength of data connections, and backup options should be considered in case the connection fails. One precaution that exists is for the aircraft to return to its take-off point if it loses signal, using systems such as Global Positioning Systems (GPS).⁹⁶ Adequate Sense and Avoid capabilities would also mitigate the risk of an aircraft losing contact with its operator, as it should behave autonomously in choosing where it travels in order to avoid a collision.



6.2.3 Cyber risk

Similar to autonomous cars, there is also the concern over vulnerability to malicious cyber interference for aircraft. UAS need to be strongly protected against hacking, to prevent unintended uses or theft of a vehicle. There could also be concerns of stealing data a UAS is collecting, which may be sensitive for the operator. Similar to this is the general risk that UAS can pose to privacy, especially when used for aerial surveillance. If a camera-equipped aircraft is going to travel over long distances, including over built-up areas, it needs to be ensured that operators are not illegally or unreasonably collecting data on individuals. Privacy risk is likely to be a contentious area as UAS come to be used commercially, especially as aerial surveillance is a common application of aircraft.

²Sense and Avoid technology enables an aircraft to detect oncoming obstacles and move itself out of their path

7 INSURANCE IMPLICATIONS

Having looked at the risks, the role of insurers in addressing these risks can be considered, as well as the business opportunities available to the industry. In this area of new and potentially revolutionary technology, insurance can have a role to play in facilitating risk transfer and encouraging high safety standards in situations where a worst case scenario may result in injury, death and spiralling costs. Because potential losses may be high, a commercial market for autonomous and unmanned technology is unlikely to evolve unless insurance is available. Autonomous and unmanned vehicles are a big unknown in many ways, and by careful scrutiny and mitigation of new risks, insurers can assist in the groundwork for adequate regulation. In the absence of received wisdom, they may play a part in determining how much testing and verification is required for public availability of autonomous and unmanned technologies. The appropriate insurance policies for autonomous and unmanned vehicles will vary from country to country according to local laws such as what cover is legally required for operation.

Cyber Coverage

Cyber coverage is an area of insurance that is still evolving to suit the needs of a digital era. As autonomous and unmanned vehicles become more commercially available, cyber risk policies will most likely be developed to suit the needs of stakeholders such as operators, systems designers, manufacturers, and infrastructure providers. At a point at which heavily digitised and networked vehicles are in use, there are a number of ways in which cyber coverage may be needed. For users, there will be scope for exposure to the costs of investigating data breaches or malicious interference, for defending violated privacy, and for repairing damaged systems. Service providers may want coverage against reputational damage and compensation to those affected by disruption or breaches of their systems.

Currently, bodily injury and physical damage are not often in the remit of cyber insurance, but the implications of a cyber attack or failure on a moving vehicle mean that this is likely to be seen as a significant exposure. Consideration would also need to be given to the scope and availability of terrorism coverage. Cyber and cyber terrorism coverage could be available as policies separate to other motor and aviation related policies, but given the increasing levels of dependence on computerised systems in vehicles, it is possible that it will become a facet of the other coverages. Cyber coverage could be a particular area of insurance growth with the development of increasingly computerised vehicles.

7.1 AUTONOMOUS CARS

7.1.1 The transformation of motor insurance?

The advent of autonomous cars could revolutionise the world of motor insurance. Autonomous cars could potentially lead to a substantial reduction in motor insurance claims if accidents significantly reduce in frequency. Lower claims would be expected to result in lower premiums, and tighter profit margins.⁹⁷ Some might argue that if cars really do become crashless, there may not even be a need for motor insurance.⁹⁸ However, some element of risk would be retained by the owner of a car. Damage or theft can still occur when a car is parked in a driveway, and for the present at least, cars with semi-autonomous capabilities are more expensive than their traditional counterparts. It is possible that this risk could become part of a household contents policy coverage.

The role of claims analysts and loss adjusters could change in line with the different availability of data on the frequency and nature of accidents. In some ways it may make assessments easier because it would be possible to see data such as what speeds vehicles were travelling at. An accident caused by autonomous technology, however, would need extensive software and hardware analysis expertise in order to understand how and why it occurred. As sensors and computers become more commonplace in cars, and some driving responsibility is devolved to the car, an increase in telematics-based policies could be an option. Premiums could be better matched to exposure rather than based on proxies, and in the event of accidents, the car's 'blackbox' could be examined. Whereas at present insurers using telematics devices incur the cost of their fitting, in the future the data may already be collected, making telematics a more viable option.

7.1.2 Liability

The question of where liability rests in the event of an accident caused by an autonomous car will be important to insurers. As discussed in section 3.5, at present in the UK liability rests with the driver/user of a

car, even if their actions are not at fault, although they and their insurer may pursue subrogation rights with the manufacturer. Insurers would need to be prepared for such cases.

The current stance could also potentially be changed to assign more liability to manufacturers, especially if a point were reached whereby users were no longer expected to even oversee the autonomous driving of their car. If such changes were to occur, motor insurance could change substantially to be something more like product liability insurance. Insurers would need to know less about the users of a car, and more about different models of cars themselves.

International insurers would also need to consider how liability laws vary in other countries, and how this could affect developments. For example, the Center of Automotive Research (CAR) has noted that autonomous cars are unlikely to first emerge in the US because of their tough litigation culture.⁹⁹ It could be in insurers' interest to press for legal clarification on where liability sits in the event of a collision caused by a (semi) autonomous vehicle. In line with aviation, and to support manufacturers who are likely to resist liability being moved in their direction, insurers could also support liability limits for manufacturers, as is done for air carriers under the Warsaw convention of 1929.¹⁰⁰

7.2 UAS

Since the commercial UAS market has potential for large growth, subject to the development of safe technology and suitable regulation, there would also be a big market for UAS insurance coverage. There are opportunities for providing insurance to both UAS manufacturers and operators. The different types of insurance coverage relevant to UAS are the same as those for traditional aviation risks, with the exception of passenger liability cover assuming UAS do not transport people. Consideration would need to be paid, however, to the new risks posed by UAS and the lack of experience in their operation.



7.2.1 Hull coverage

The cost of UAS equipment, both aircraft and ground controls, may be significant. Hull coverage will be relevant to protect owners against the cost of loss or physical damage incurred. As the size of UAS can vary wildly from insect to jet airliner sized, the amount of hull coverage could also vary significantly. Other equipment attached to the UAS, which may vary according to its intended application, would also add variance to hull coverage. For example, aircraft used for media purposes may incorporate expensive cameras.

7.2.2 Cargo coverage

One potential, although probably not imminent, application of UAS is for delivery purposes. This could be at the level of individual parcels, or large batches of cargo in a distribution chain. The nature of the cargo would need to be considered as it could vary from books to petrochemicals. The way it is delivered would also need to be considered, such as whether it is dropped from a height, or securely unloaded. Cargo coverage

would be relevant for suppliers or purchasers of goods transported by UAS, however this is not expected to become common in the foreseeable future

7.2.3 Third party liability coverage

As with manned aircraft, it is likely to be an important condition of flight for UAS operators to have liability coverage for third party personal injury or property damage, in case an aircraft accidentally crashes, or an object were to fall from it. Factors to consider when assessing liability coverage will include the size of the aircraft, the area it will be flown in, the purpose of its operation, the expertise and attitudes shown by its operator, and the safety features of the aircraft.¹⁰¹

Third party liability coverage may be something that is required by law, depending on the country where the risk is based. For example, in the EU, UAS are currently required to be insured to the same levels of manned aircraft.¹⁰² Third party liability coverage availability is likely to be particularly important for the development of the commercial UAS market, as a primary risk associated with UAS is the risk of an aircraft crashing into people or objects on the ground, or indeed into another aircraft.

7.2.4 Product liability

For manufacturers of UAS, product liability policies may be required. The scope of this may be broader than for traditional aviation risks if the insured UAS has autonomous capabilities, or if contact is lost with an operator and backup safety features are not adequate. At present autonomous functionality of UAS is a more distant prospect than for cars, but this could become a more relevant issue in the future.

7.2.5 Other

There are also incidental areas in which UAS can affect insurers. The surveillance capabilities of many UAS can be used to gather data that supports other insurance policies. For example, in the event of crop damage, a farmer could compare information on the damaged crops compared to historical data of normal crops, for use in submitting a claim.¹⁰³ Use in weather monitoring such as in recording hurricane characteristics could contribute to more reliable modelling. They can be used to assess damage levels, particularly in inaccessible areas, for use in claims handling. It is also conceivable that a UAS could be used as security measure when protecting a risk such as a large building, or an event. Insurers could take the use of a UAS into account when pricing such a risk.

There is scope for insurers to play a role in developing standards of good practice for operating UAS, particularly where there is a lack of regulatory specification. In helping to enable the early stages of commercial operation of UAS, it is important that insurers are only insuring responsible operators. By requiring proof from the insured of a safety and privacy conscious mind-set, insurers can help protect against cases of misuse, which at the formative stage of the market could set back UAS acceptance considerably. In a field which could be very dangerous without adequate risk management, the expertise of insurers could be important.

8 CONCLUSIONS

Whether it be through transport, industry or research applications, autonomous and unmanned vehicles have great potential to change the world we live in. In order to achieve a widespread take-up of this machinery, the hurdles to overcome are not so much technological but questions of safe and practical implementation. Developing adequate regulation and codes of practice may take time, and public trust is not always forthcoming for new technology, but achieving this is likely to mean creating new business opportunities.

It is hard to predict timescales for goals such as fully autonomous driving and everyday use of UAS. One thing that may influence progress is the observed safety standards of autonomous technology – it could only take one prolific accident to significantly affect public trust and damage manufacturers' reputations. On the other hand, if it is shown that, for example, semi-autonomous cars cause a significant decrease in collision frequency, this could accelerate acceptance. As the main risk of these technologies, collision, can cause injury, death, and property damage, achieving extremely high safety standards is likely to be essential for the future of autonomous and unmanned technology.

As vehicles become increasingly computerised and networked, cyber risk is likely to be a more prominent concern. In the case of remotely operated vehicles, there would need to be adequate back-up plans in case of a loss of communications with the controller. With the increase of cyber risk, there will be scope for writing more cyber insurance. Another aspect of increased computerisation, especially in the case of cars, is that insurers can take advantage of data facilities already present in the vehicle to use a more telematics based approach to premium pricing. This could allow better matching of exposure to premiums, and more individually tailored policies.



With a shift towards autonomous technology and away from human operators, the landscape of insurance, especially motor insurance, may change dramatically. There would be a greater need for the expertise of data analysts to understand why an autonomously operated vehicle has failed in the event of an accident. If, as evidence suggests, ADAS car features drastically lower collision rates, motor insurers would have to adapt to a new levels of premiums and claims.

At a very advanced point of autonomous car development and take-up in the future, it could be possible that drivers are no longer legally required to attentively supervise a car's driving, and can instead do things like read a book or sleep. If such a point were reached in the future, it may be possible that there is more onus of liability on the car manufacturer rather than owner, if the car is being trusted to entirely conduct a journey. This would likely, however, not be a consideration until much further into the future.

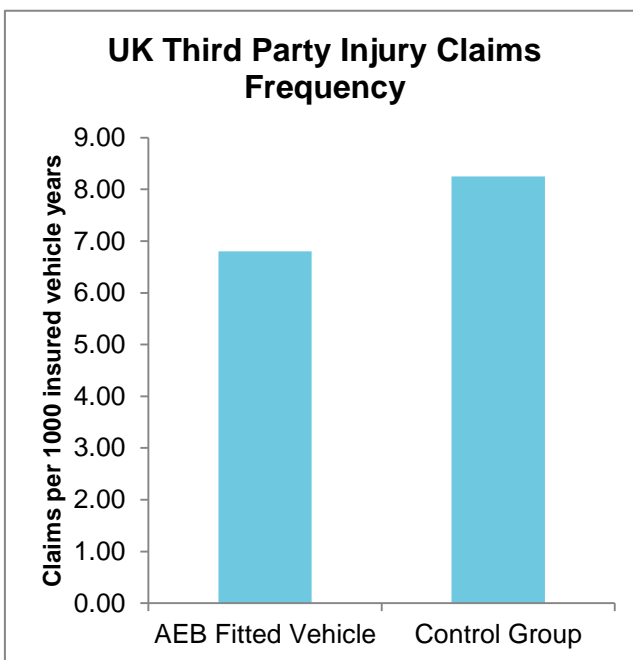
There may not be an overnight revolution of self-driving cars on the roads and UAS in the skies, but autonomous technology is expected to become increasingly applied to cars, and subject to suitable regulation and organisation, there is great potential for commercial UAS usage. For autonomous and unmanned technology to become a reality in our world, the risk transfer abilities of insurance and risk management skills of insurers will be key. With the advent of new technology and the risks it brings with it, there is likely to be scope for insurers to write new business.

9 APPENDIX: (SEMI) AUTONOMOUS CAR FEATURES

Autonomous Emergency Braking (AEB)

AEB is a function which, generally using radar or lidar sensors, detects potential upcoming obstacles, and takes action to prevent a collision. When the system determines that the situation is critical, it will sharply apply the brakes to come to a safe stop. Research into the effectiveness of AEB supports positive safety conclusions. A study by the European Commission found that the widespread adoption of AEB could reduce accidents by up to 27%, saving 8,000 lives a year and saving £3.9-£6.3 billion.¹⁰⁴ The UK's Insurance Group Rating Panel has lowered the group rating of AEB-fitted cars, so that their drivers should pay lower insurance premiums, as they are deemed less likely to crash. The European New Car Assessment Programme (Euro NCAP), an EU backed assessor of car safety, has given awards in recognition of high safety standards to a number of major manufacturers for their AEB systems.¹⁰⁵

On some cars, such as all new Volvo models³, AEB fitment is standard, but on most cars it is an optional add-on, often as part of a safety package. This optionality limits the take-up of AEB at present. There are signs, however, that in the near future it will become rapidly more widespread. Euro NCAP have announced that from 2014 AEB fitment will be a factor in its safety assessments, and that without AEB it would be "practically impossible" for cars to attain a top five-star rating.¹⁰⁶ It also "hopes that European authorities will soon require AEB as mandatory on all new vehicle types".¹⁰⁷ The ratings of Euro NCAP are important for a car manufacturer's reputation, and five-star ratings are increasingly seen as a development goal for a new model.¹⁰⁸ By making AEB a near essential component of such a rating, it is likely to become a de facto required feature on new cars in the next few years. Official governmental mandates may follow, which would significantly increase the number of AEB-fitted cars on the roads, and familiarise drivers with autonomous functionality.¹⁰⁹



Source: Thatcham Research member claims data¹¹⁰

Adaptive Cruise Control (ACC)

Adaptive Cruise Control (ACC) is similar to traditional cruise control, but instead of maintaining a set speed, when activated it maintains a safe distance from the car in front. It usually uses a radar, laser or camera sensor on the front of the car which detects obstacles ahead. If the car in front slows down, so does the ACC car. When traffic in front speeds up again, the ACC car does too.

Lane Keeping Assist

This function can use sensors including video sensors, usually mounted somewhere around the windscreen, laser and infrared sensors to detect lane markings. If the system detects that the car is moving too close to these markings, it will warn the driver and/or correct steering to reposition the car back into its lane. Over the last decade a number of manufacturers have added this as an option to new models. Lane Keeping Assist technology is significant because it in theory allows the driver to be 'hands free' – a milestone on the path to handing over driving control to the car.

Automatic parking

Using sensors mounted on front and rear bumpers, some cars can automatically park themselves in parallel or right-angle parking spaces. Systems have also recently been demonstrated where a driver can get out at their destination and instruct the empty car to park itself – and at the command of a smartphone retrieve it again later.^{111,112} This autonomous parking system is not yet commercially available, although there have been industry suggestions that it could be in five to ten years.¹¹³ However, its use raises questions universally relevant to autonomous driving, such as whether it can be made acceptable in law for a car to be operating without a driver's supervision. Autonomous parking could be an area where these questions could

³ Except the Volvo XC90

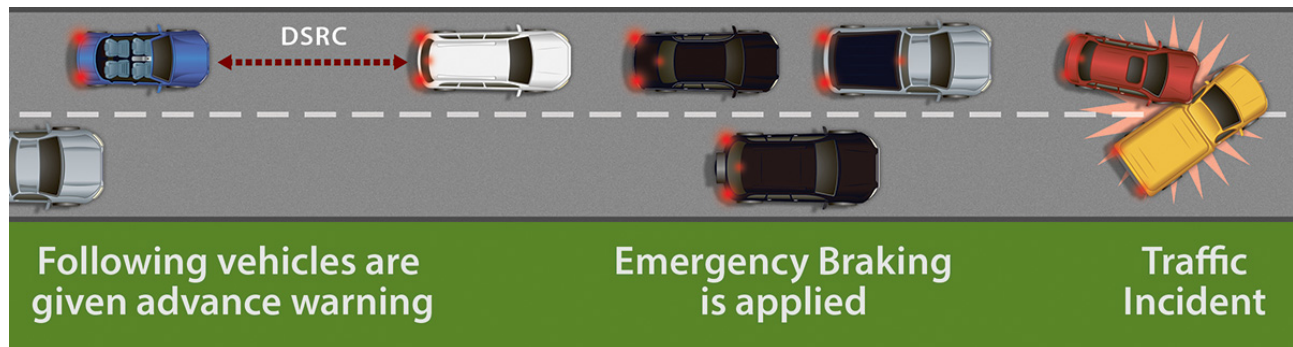
be addressed in more restricted circumstances – a car-park’s controlled conditions could make it suitable for a place to begin integration of fully autonomous driving.

Networking

An area of development which is not yet so commercially available is the use of wireless networking with vehicles. Unlike the other features mentioned above, for this to be useful, a critical mass of take-up would need to be achieved. It comes in the forms of:

- > inter-vehicle networking in the local area, known as Vehicle to Vehicle (V2V)
- > networking between a vehicle and an infrastructure system, known as Vehicle to Infrastructure (V2I)

The collective term for this networking technology is V2X.



Use of V2V and AEB could avoid a pile-up scenario following a traffic incident. Source: [Nuvation Engineering](#)

V2V can be used to prevent collisions by rapidly sharing data such as a car’s speed, location, and activity. For example, a vehicle could transmit a warning signal if the brakes are slammed on, giving a fast warning to drivers behind that they too need to stop. This could in turn be integrated with autonomous driving features such as AEB. Another application of V2V under development is for road trains on motorways, where cars join together and follow a lead vehicle, allowing them to behave as a group. In 2012, the first public test of such a road train was carried out on a motorway near Barcelona.¹¹⁴ As well as assisting in traffic management and avoiding collisions, road trains could provide a more fuel efficient style of transport, as there would be less congestion and more consistent road speeds. The aerodynamic nature of the formation is also relevant: one study found that this can improve fuel efficiency by up to 30%.¹¹⁵

If a point of advanced take-up were reached, it could make sense for the motorway itself to be in control of the traffic coming and going, and become involved in V2I communications. While ADAS and V2V would come into usage through consumer choice and institutional recommendations, for V2I to become relevant, governments would need to invest in digital infrastructure. There are many ways in which this could be done to assist autonomous driving, for example, traffic lights and road signs could transmit electronic signals.

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