1. Executive Summary

1.1 There is an important distinction between automated and autonomous vehicles. The terms are often used interchangeably but incorrectly when describing current and future applications.

1.2 There already exists a wide range of automated capabilities within both civil and military aviation sectors, including space, with the likelihood of manned and unmanned aircraft systems becoming more autonomous with technological and regulatory advancement.

1.3 The scope of autonomous flight is more wide-ranging for aircraft than for cars as they are not restricted by existing physical infrastructure and because there is a wider range of designs and constructions of UAS, making it more challenging to predict the development path of the technology.

1.4 In the same way that a human driver will still likely be required to oversee the highly-automated operation of a car for the foreseeable future, a remote operator or team of operators are likely to remain a requirement for airborne vehicles. This is unlikely to raise any new ethical issues.

1.5 Increasing the application of automated and autonomous technology in manned and unmanned aircraft will not work in concept if it is simply designed to replace the human. Operational weaknesses, such as loss of situational awareness, develop if a human does not know what part they play in the overall system.

1.6 The hazards posted by the use of automated and autonomous UAS are similar to those posed by autonomous cars, but with significantly greater consequences when something goes wrong. Regulations in place to limit the freedom of UAS operators should, however, be reviewed and changed when technology advances.

1.7 The legislative and regulatory environment, as well as and airspace architecture, will also need to adapt in a risk-based way and incorporate UAS to maximise the sector’s economic potential. The Government’s planned UAS Strategy and Modern Transport Bill provides the ideal opportunity to resolve legislative and regulatory barriers to growth. Regrettably progress appears to have stalled after the EU referendum.

1.8 Trials have been laying the foundations for the regular sharing of the skies between manned and unmanned aviation. Despite the optimistic forecasts for growth, rethinking legislation and regulation to suite commercial applications of UAS is a challenging task. However, countries that are early adopters of UAS in controlled and unsegregated airspace could be well placed to capture the commercial and economic opportunities.
1.9 Government support should not focus on a few narrow commercial applications, particularly those based on imported technology as this will not help the UK industrial base to achieve its growth potential.

1.10 Automation and autonomy will be dependent on satellite systems, especially navigation. The Government’s strategy should recognise the role of space technology in autonomy and must continue to support the UK’s leading role in the space sector as a necessary element in delivering autonomy advances.

1.11 As with autonomous cars, there is a concern about the cyber vulnerability to automated and autonomous manned and unmanned aircraft systems. Systems need to be protected from hacking, for example to prohibit non-authorised operators from taking control, through the provision of high standards of systems resilience and regulation.

1.12 Without preventative action, Brexit will lead the UK’s withdrawal EU-funded research and space programmes relevant to the development of autonomous technology.

2. About the Royal Aeronautical Society

2.1 The Royal Aeronautical Society (the Society) is the world's only professional body dedicated to the entire aerospace community. Established in 1866 to further the art, science and engineering of aeronautics, the Society has been at the forefront of developments in aerospace ever since. The Society seeks to: i) promote the highest possible standards in aerospace disciplines; ii) provide specialist information and act as a central forum for the exchange of ideas; and iii) play a leading role in influencing opinion on aerospace matters.

3. What are the potential applications for autonomous vehicles?

3.1 At the outset, it is important to clarify the distinction between automated and autonomous vehicles, as the terms are often used interchangeably but incorrectly. An automated vehicle is one that follows a series of pre-programmed commands but lacks the capacity for independent decision-making. If an automated system encounters a problem, it can only follow a script; it is not capable of devising its own solutions to effectively cope with demanding circumstances. An autonomous vehicle is given a task or mission, and is programmed to be able to take decisions intelligently on how it will perform that task without human intervention.

3.2 Systems where there is no active and direct human intervention across the various stages of a given decision-making process might appear to be autonomous but might just be highly automated with a human over-ride. The US Navy Office of Naval Research (used by SEAS DTC) provides a helpful explanation of the various levels of autonomy from human operation to full autonomy\(^1\).

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\(^1\) Williams, R. *BAE Systems – Autonomous Capability Overview*. BAE Systems, Preston, Slides 5-6.
3.3 There already exists a wide range of automated capabilities within both civil and military aviation sectors, including automatic landing systems for use in poor weather, automated navigation, anti-collisions systems and engine controls. In the field of unmanned aircraft systems (UAS), automation is already underway in areas such as take-off and landing and navigation, with the likelihood that UAS will become more autonomous with technological and regulatory progress.

3.4 The development and application of increasingly automated and autonomous systems in civil and defence aviation, is advancing at a rapid pace because of the expected benefits the technology will yield, including efficiency, accuracy and enhanced safety of operations, while concurrently potentially reducing workload and training requirements and costs. Automated and/or autonomous aircraft systems could enable access to places that would otherwise be dangerous or impossible for human pilots to reach. Automated or autonomous systems can also replace roles that would be too repetitive or tedious for people to carry out for extended periods of time where high levels of focus would be required.

3.5 The interest and advancement of automated and autonomous aircraft systems and technology is driven in large part by the growth in civil and military UAS. UAS are expected to play a greater part in the future of aerospace and aviation owing to the promise of military capability enhancement and economic gains. Advances in artificial intelligence (AI) are creating new opportunities for UAS, creating new business models, modes of operation and innovation in the aerospace sector. Swarms of UAS able to share data, unmanned combat air vehicles (UCAV) that could react to and respond to pop-up threats, or UAS programmed with the accumulated knowledge of thousands of human pilots and able, even, to learn from mistakes to optimise performance, are all possible applications of greater autonomy in aviation.

3.6 There is an expectation that armed UAS, with the capability of responding to verbal and digital commands thanks to AI technology, may eventually evolve and become common place, even operating alongside human piloted aircraft. A US Air Force Research Laboratory funded project, ALPHA, is an AI system trained by an Air Force expert in air combat. In synthetic-based trials, the AI consistently bested human pilots – even when hampered by being given inferior aircraft.²

3.7 The scope of use of autonomous flight is more wide-ranging than for cars, particularly certain sizes and weights of UAS, as they are not limited by existing infrastructure, like roads. Unlike cars, UAS offer a wider variety in the way they are constructed and developed, which make it more challenging to predict the development path of the technology. The commercial availability of autonomous UAS is more difficult to foresee given the sheer number of opportunities, including Personal Air Transport (PAT), and current restrictions of operation in a multitude of civil and military environments due to safety, ethical and legal concerns. UAS (automated and autonomous) technology raises a number of questions about the possibility of safe integration into a well-established, regulated airspace.

² Gallagher, S. (2016) AI “pilot” bests human air combat experts in simulated dogfights. arsTechnica, USA
3.8 In the same way that a human driver would still be required to oversee the highly-automated 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 Remotely Piloted Aircraft Systems (RPAS)\(^3\) is often preferred as a reminder that although these vehicles are unmanned, they still rely, to some extent at least, on ground-based operators.

3.9 Beyond terrestrial applications, autonomous vehicle technology has applications in the satellite and space exploration domain. Satellites operate as semi-autonomous vehicles in space. In this context, autonomy is typically applied to the management of on-board systems in order to achieve a high degree of resilience to external disturbances or equipment faults, while minimising dependence on human oversight. The expected growth of ‘mega-constellations’, consisting of many hundreds of satellites, places major demands on autonomy as a necessary element for maintaining effective control without an equivalent, uneconomic growth in ground-based oversight. Autonomous ground vehicles have a developing role in robotic exploration of the solar system. Remotely operated and semi-autonomous rovers have been deployed on both the Moon and Mars.

4. What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?

4.1 The application of highly-automated technology in manned aviation is already well-established, and yielding significant benefits, particular in terms of safety. Early aircraft operations were highly hazardous and regular incidents resulted in numerous fatalities. Along with improvements to aircraft structures, power systems, aerodynamics and construction techniques, the advent of the modern flight management systems has enabled commercial aviation, in particular, to become safer as a mode of transport than road vehicles.

4.2 Compared, with 2014, the global accident rate involving scheduled commercial operations decreased by 7% in 2015, which equates to 3.0 accidents per million departures in 2014 to 2.8 accidents per million departures in 2015\(^4\). The 474 fatalities in 2015 are a decrease from the 904 fatalities in 2014 – despite the loss of Germanwings and Metrojet, which caused significant loss of life\(^5\). Over 1.2 million people die each year on the world’s roads, with up to 50 million people incurring non-fatal injuries as a result of road crashes\(^6\). The number of deaths on the world’s roads has plateaued against a 4% increases in global population and 16% increase in motorisation\(^7\).

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\(^3\) The International Civil Aviation Organisation (ICAO) defines RPAS as a form of UAS, which is non-autonomous in its capacities, the aircraft being subject to direct pilot control at all stages of a flight, despite operating remotely from the pilot.

\(^4\) International Civil Aviation Organisation (2016) Safety Report. ICAO, Montreal

\(^5\) Ibid.


\(^7\) Ibid.
4.3 Today pilots monitor systems but leave routine flying to the autopilot. Aircraft fitted with precise navigation instruments means that pilots will rely on autopilots to land in poor visibility conditions. The new generation of highly-automated fly-by-wire systems in aircraft can be programmed to carry out precise adjustments to control surfaces automatically, keeping the flight more stable. Equally, engine management systems work in co-ordination with flight management systems to ensure optimum efficiency and economy of operation, thus addressing fuels costs and emission challenges. Also, the development of virtually autonomous Traffic Collision and Avoidance Systems (TCAS) has made a major contribution to safety in what is increasingly busy airspace.

4.4 Pilot error is still the most common contributory factor in aviation accidents, although less so in terms of routine flight tasks, despite the high levels of automation involved in aircraft design and operations. Increasing the application of cockpit technology does not work in concept if it is simply designed to replace the human. Operational weaknesses, such as loss of situational awareness, develop if the human does not know what part they play in the overall system. Pilots, as well as the people managing complex automated systems on the ground, need to be trained sufficiently with the skills and competences required to operate today’s complex automated aircraft. This can be particularly challenging when determining how much knowledge the flight crew need to have about the complexities and interactions of automated systems on the latest generation of airliners. Although highly reliable, when problems do occur it can be extremely difficult for the flight crew to understand what the aircraft is trying to do and how best to intervene to ensure a safe outcome. It is prohibitively expensive to give all flight crew sufficient training to cope with every possible emergency, particularly given the rarity of such events, and there is significant reliance on the experience of the flight crew and their ability to work effectively as a team. This is issue is only exacerbated in autonomous systems where those who may need to respond to and address malfunctions are remote from the system, and probably poorly places to undertake timely diagnosis and recovery action.

4.5 The emergence of greater autonomy in UAS has the potential to create opportunities to extend the widespread benefits to public service and commercial operations that are already offered by human operated UAS (or RPAS). Uses include crop monitoring, infrastructure monitoring and maintenance, natural disaster response and police surveillance. In certain commercial operations, such as parcel delivery, automated UAS could have their own segregated airspace with their own Air Traffic Control (ATC) system, with which manned aircraft would have to comply if they wish to enter. Governments, regulators and the industry will need to understand how the automated system and the human will coexist.

4.6 The hazards posed by the use of automated and autonomous UAS are similar to those posed by autonomous cars, but with the significantly greater consequences when something goes wrong. The biggest is collision with people or property, and manned aircraft or other UAS. Regulations are in place to limit the freedom of operators to fly UAS near people and built-up areas, as well as other aircraft. These regulations are

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8 Airbus.com: Fly-by-wire
9 Civil Aviation Authority Regulations relating to drones and unmanned aircraft
currently being reviewed and should change when technology allowing civilian UAS to operate out of sight of the operator is proven to work safely. Highly reliable ‘sense/detect and avoid’ capability must also be proven to avoid conflict with other aircraft and UAS.

4.7 Military UAS are still limited to segregated airspace or flight above 60K feet or for a few low level operations under the ‘due regard’ requirement\(^\text{10}\). Currently, military UAS are deconflicted carefully, either flying in empty ranges, conflict zones or under close supervision to operate under or between ATC civil routes.

4.8 Another risk is loss of a data link to the controller in highly automated but not completely autonomous UAS. Civil and military UAS are operated remotely and require a reliable data link between the UAS and operator, which, if lost, could result in an accident. Higher levels of automation, whereby a UAS operating beyond-visual-line-of-sight (BVLOS), becoming distressed would be able to land safely according to pre-programmed scenarios or make a decision itself (autonomously) on a safe landing place, are under development and will improve safety levels.

4.9 Autonomous technology, deployed in the satellite/space exploration context, is perceived as a benefit for space applications. Greater autonomy allows for greater cost efficiency, improved resilience and higher returns in both commercial operations and scientific missions. The European Space Agency’s (ESA) Huygen’s probe that landed on Saturn’s moon Titan was fully autonomous (the software being supplied by a UK company). Long delays in communication (for example for missions to Mars and other planets) emphasise the need for vehicles to sense, interpret and respond to their environments with minimal human intervention.

5. How much is known about the potential impact of deploying autonomous vehicles in different sectors?

5.1 Further to the Society’s response to Question 4, there is an already high level of automation in the commercial aviation sector. A comprehensive, though not exhaustive list of the main advantages of automation in manned aircraft is set out by the European Aviation Safety Agency (EASA)\(^\text{11}\).

5.2 The potential impacts of the deployment of automated UAS, and in the future autonomous UAS, can be inferred from the current use of RPAS in a wide range of areas. These uses are already well documented elsewhere, such as the House of Lords European Union Committee report on Civilian Drones (2015)\(^\text{12}\).

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\(^\text{10}\) The military do what they can to avoid impacting civil operations, mostly restricted to low altitude operations.


5.3 Autonomy is recognised as a major beneficial technology in the space sector, where its use has been actively pursued for many years, with UK companies having a strong heritage.

6. What is the scale of the market for autonomous vehicles?

6.1 Autonomy in aviation creates economic opportunities for the aerospace sector itself but also supports growth and efficiency of operations in sectors that deploy or will deploy automated aircraft systems. A study by PwC on the commercial application of UAS technology concluded that the “emerging global market for business services using UAS is valued at $127bn”\textsuperscript{13}.

6.2 Legacy aviation and aerospace companies are incorporating UAS into their business or seeking to enter the fast-growing market, through developing UAS themselves, acquiring innovative start-ups or by partnering with UAS companies in ways that complement their businesses.

7. Is the scale of current and planned demonstration facilities for autonomous vehicles sufficiently broad and ambitious?

7.1 More challenging applications, such as pilotless firefighting aircraft and even conventional freighter aircraft, do not appear to be being considered as strongly as they could in part because the regulatory environment does not make this viable. Progress of the European ‘Specific’ category of UAS regulations\textsuperscript{14} has the potential to improve this.

8. Is the Government doing enough to fund research and development on autonomous vehicles, and to stimulate others to do so?

8.1 No specific government funding actions are in place for autonomy in the space context. The European Space Agency (ESA) site at Harwell includes technology for robotic exploration within its remit.

9. How effective are Innovate UK and the CCAV in this area?

9.1 The Government supports aerospace research through the Aerospace Technology Institute (ATI), a joint Government and industry investment that aims to maintain and increase the UK’s competitiveness in aerospace design and manufacture. Innovate UK is the delivery partner for the ATI research and technology programme.

9.2 Development and demonstration of autonomous aerospace technologies is already one of the new architectures that will benefit from some of the £3.9 billion Government and industry funding for UK aerospace R&T up until 2026\textsuperscript{15}.

\textsuperscript{13} PwC (2016) Clarity from above: PwC global report on the commercial applications of drone technology. PwC, Poland

\textsuperscript{14} European Aviation Safety Agency: Civil drones (Unmanned aircraft)

\textsuperscript{15} Aerospace Technology Institute (2016) Technology Strategy and Portfolio Update 2016: Raising Ambition. ATI, Cranfield
9.3 No specific government funding actions are in place for autonomy in the space context.

10. Is the environment for small and medium-sized enterprises (SME) working in this sector sufficiently enabling?

10.1 UK SMEs are well placed to lead the UAS industry’s expansion found the European Commission (EC)\(^\text{16}\). This is a result, in part, because the “most rapid commercial market for growth [in civilian drones] has come from the small RPAS. In the UK, this has mainly involved the sale of services…”\(^\text{17}\).

10.2 The current regulatory framework for UAS inhibits the application of autonomy in UAS because of the requirement for civilian UAS to remain within visual line of sight. As technologies develop and trials are completed into the viability of ‘sense/detect and avoid’ technology and the use of BVLOS solutions, the regulatory environment and airspace architecture will need to adapt in a risk-based way and incorporate these UAS to maximise the sector’s growth and economic potential. This is beginning with the outline of the ‘Specific’ category of RPAS presented in the recent ‘prototype’ regulation from EASA.

10.3 After initially backing research into the commercial application of large UAS through the Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTREA)\(^\text{18}\) consortium, the UK Government removed its support for larger UAS in favour of small UAS – often side-lined in the past – with pathfinder demonstration projects leading the way in the commercial deployment of civil UAS, albeit with somewhat limited support for indigenous UAS platform development of any size.

10.4 At a Royal Aeronautical Society conference in October 2015, the Government set out its vision for civil use of UAS in the UK, in particular companies being able to operate BVLOS:

“To create an environment and enabling infrastructure (legal and regulatory framework and policy) in the UK that: drives growth in the private drone sector (users, manufacturers, services); facilitates public sector adoption (increasing efficiency and capability); and provides reassurance on societal concerns (safety, security, privacy and data protection).”\(^\text{19}\)

10.5 The Government’s plans\(^\text{20}\) for publication of 10-year UAS strategy in the summer of 2016 to deal with regulatory issues surrounding the development and more widespread use of UAS, with the objective of becoming a world leader in the sector,


\(^{18}\) astrea.aero


\(^{20}\) Sciencewise Further Government statements on the role of the current drones dialogue in 10-year strategy
seem to have stalled following the outcome of the EU referendum, which is disappointing. The Modern Transport Bill announced in the 2016 Queen’s Speech is the ideal opportunity to resolve legislative and regulatory barriers to the growth of the sector.

11. Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?

11.1 In the provision of air navigation services, automation is already being widely used alongside high levels of automation in the aircraft they are serving. Today the air traffic controller still makes the decision, but is supported by automated information and advice. NATS is already considering “the implications of introducing more automation into air traffic control...for example providing earlier warnings of potential conflicts, reducing the likelihood of human error and enabling controllers to handle aircraft more safely.”

11.2 Changes to airspace architecture are not completely dependent on the development of greater autonomy in manned and unmanned aviation. The application of automated systems should improve the way airspace is controlled, including handling higher traffic volumes and even a mix of manned and unmanned aircraft systems with a reduction in dependency on the controller. With greater autonomy controllers might change the focus of their jobs and become supervisory, but it is likely for the foreseeable future that human roles will continue.

11.3 The introduction of trajectory management for civil aircraft movements, with their precise paths pre-programmed from gate to gate, and all aircraft constantly broadcasting their positions and trajectories to others, and adjusting their flightpaths to take account of potential conflicts, will largely remove any practical difference between manned and unmanned flights and controlled and uncontrolled airspace.

11.4 Plans for the integration of automated or autonomous UAS in controlled airspace would require changes to the way airspace is managed rather than controlled. UAS flying in controlled and unsegregated airspace would be controlled in the same ways as a manned aircraft, at least when there is a pilot on the ground with whom controllers can communicate. The changes required in the immediate term will be legislative and regulatory in order to allow UAS to operate in airspace usually reserved for manned commercial aircraft.

11.5 Trials have been laying the foundations for the regular sharing of the skies between manned and unmanned aviation. Yet, despite the optimistic forecasts for growth, rethinking legislation and regulation to suit commercial applications of UAS is a challenging task requiring considerations of safety and privacy issues. Countries that are early adopters of UAS in controlled and unsegregated airspace could be well placed to capture the commercial and economic opportunities from this burgeoning sector.

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11.6 The important role of the space sector in enabling terrestrial autonomy should be noted, as relevant to ground vehicles, aircraft and marine vessels; indeed, autonomy substantially increases the critical dependence of systems on satellite systems, especially navigation. Three space technologies underpin many autonomous vehicle activities:

- Satellite navigation (e.g. Global Positioning Service (GPS); Galileo) for position, velocity and time information;
- Satellite communications (satcoms) for remote monitoring and control (particularly for vehicles operating in remote areas on land, at sea and in the air), and for data transmission; and
- Satellite navigation enhancement systems (e.g. European Geostationary Navigation Overlay Service (EGNOS), mounted on satcoms) today offering greater positional information and “Safety of Live Service” for aircraft landing, but potentially applicable to other vehicles.

11.7 These technologies play a central and growing role in the operation of (semi-) autonomous systems, including road vehicles and deployment of military systems in-theatre (e.g. surveillance UAS operations in Afghanistan – guided via GPS; linked via satcoms).

11.8 UK companies have gained key roles in these technology areas. In satcoms, for example:

- Inmarsat owns and operates the satellites that not only provide reliable communication services to the world’s shipping and air fleets, but also carry in-flight elements of the EGNOS system; and
- Airbus Defence and Space (D&S) is the prime contractor for many of the world’s communications satellites and operates the Skynet 5 fleet of satellites that provide reliable communications for Britain’s military forces worldwide.

11.9 In the Galileo satellite navigation programme (Europe’s version of the US GPS system) the UK Government has taken a leading role in defining and managing the security aspects of the programme (including chairing the Galileo Security Accreditation Board) and UK companies lead the development of many of its critical elements of Galileo, for example:

- SSTL built the payloads for all 22 of the operational Galileo satellites and also built the complete first Galileo prototype satellite;
- CGI is providing the security facilities, such as the cryptographic key management facilities, and security services that will ensure Galileo is cyber secure;
- Airbus D&S is leading the development of the control facilities that operate the constellation of satellites.

11.10 In addition, satellite remote sensing provides key inputs to modern mapping systems and weather forecasting (of particular relevance to UAS and marine vessels).
12. How might a move from current levels of highly automated vehicles to their extensive deployment best be managed? What do you see as the key milestones?

12.1 The path that UAS undergo towards being everyday technology is unlikely to be as uniform or predictable as for autonomous cars, given the variety of size and capabilities that different UAS have, and because they operate with less constrained physical infrastructure. The main barrier for UAS to overcome is the lack of certainty in airspace regulations and 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, including the UK.

13. Does the Government have an effective approach on data and cyber security in this sector?

13.1 As with autonomous cars, there is concern about the vulnerability of UAS to cyber threats. UAS need to be protected from hacking, for example to prohibit non-authorised operators from taking control (pirating), or to prevent theft, particular of the data being collected by the UAS, which may be personally or commercially sensitive to the operator, or representing a threat to national security when collecting aerial intelligence data. It has already been proven that UAS GPS systems can be hacked. The proliferation of UAS use closer to people or other airspace users will need to be accompanied by the application of high standards of systems resilience, and their proper regulation. Equally, the necessary further increase in Air Traffic Management (ATM) to cope with the complexities of with the integration of manned, unmanned and autonomous aircraft systems will have an increasing vulnerability to cyber-attack; indeed, there are already very significant concerns about the vulnerability of ATM systems today.

13.2 Data protection laws in the UK and at the EU level are sufficient to regulate the collection and handling of data collected by UAS. Education on the laws and their application to UAS, with enforcement where necessary, will be required.

14. Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?

14.1 See the Society’s response to Question 11 in relation of further revisions to regulation and legislation.

14.2 There is likely to be a large market for UAS insurance products as the UAS sector grows. Coverage would be offered to manufacturers, owners and operators, according to the risk posed by the size, weight and use of the UAS.

14.3 While insurance is an important component in the protection of society, it must not replace the importance of education and making owners and operators automated.

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22 BBC (2012) Researchers use spoofing to ‘hack’ into a flying drone
and autonomous vehicles aware of their responsibilities and legal obligations regarding their vehicles and use.

15. What, if any, ethical issues need to be addressed in the substitution of human judgement in the control of vehicles by algorithms and Artificial Intelligence?

15.1 In the same way that commercial aviation retains human oversight despite the high levels of automation in the cockpit and on the ground in air traffic control, UAS are likely to remain under the control and oversight, and/or to be programmed by human beings in the near term. This is unlikely to raise any new ethical issues. Concerns about the civil use of UAS mainly relate to potential negative societal impacts, for example noise, privacy and safety.

15.2 Currently, human operators of UCAVs are subject to military and international law to ensure that the use of force is justifiable. In this situation, there is nothing unethical about the deployment of automated or semi-autonomous military UAS:

“The remoteness of the UAV pilot is not inherently different from that of a F1 [fast jet] or attack helicopter pilot or even an army sniper. It does not follow that this remoteness results in an emotional or moral detachment from events...In short, ‘drones’ are no different from any other type of weapon in legal or moral terms.”

15.3 However, a completely autonomous UCAV that makes its own independent target selection and weapon release decisions would represent a significant change in military hardware and require a major reappraisal of the issues of control and responsibility.

15.4 In the military context in particular, but with some relevance to the civil environment:

“There remain...extraordinary challenging engineering and programming tasks in order to design autonomous systems able to operate in complex and messy operational environments. Such [autonomous] systems would have to be able to apply the principle of distinction between what is a legitimate military target that can be attacked in accordance with international humanitarian law, and persons who require protection, including civilian, surrendering forces and prisoners of war.”

15.5 Away from the battlefield, and in addition to the UK’s existing Code of Conduct for the Testing of Autonomous Vehicles, a proper set of “ethical” rules must be established and validated for the operation of autonomous vehicles, for example in situations where a vehicle is obliged to judge between its own safety or mission, its pilot, driver or passengers, and people or vehicles in its path.

16. What does the proposed Modern Transport Bill need to deliver?

16.1 The market in civil UAS is growing rapidly, driven largely by small, cost-effective and versatile systems with a variety of uses. The rate of increase in new market entrants for small systems is a reflection of their accessibility and low costs. The challenge is to further enable this early industrial base to a sustainable future where it could become the first in the world to be fully integrated into the manned aviation sector.

16.2 The UK has made substantial progress in this areas thanks in part to the progress so far with its regulatory framework and the pragmatic approach adopted by the UK Civil Aviation Authority (CAA). The Government must use the proposed Modern Transport Bill to set out how regulation can enable widespread public acceptance of UAS operations, how the existing base of small UAS operations can be used to enable a bigger step towards integration into controlled and unsegregated airspace and how it will take early advantage of what is happening in the civil market to accelerate the expansion of the industrial base to deliver the substantial benefits available to society and the economy.

17. How effective is the UK’s education system in delivering people with the right skills to support the autonomous vehicles sector?

17.1 Autonomy is built upon a wide spectrum of underlying enabling technologies, including satellite systems and high integrity software.

17.2 Individuals with relevant science and technology skills continue to be in high demand and can be in short supply at times, which will undermine the development of autonomous solutions if not addressed. This is not only crucial in the design and construction of systems, but also for their maintenance and operation. Design is a particular area of concern given that the safety of autonomous systems will depend very largely on safety of operation being designed in from the start.

17.3 British companies and universities are at the forefront of these developments and GATEway is one of many projects in the UK in this field. However, as with all STEM subjects, continuous effort must be made to draw the younger generations into these and related fields, in particular electronics, structures, aerodynamics and propulsion.

18. Is the Government’s strategy and work in this area sufficiently wide-reaching? Does it take into account the opportunities that autonomous vehicles offer in a wide range of areas, not just on the road?

18.1 The industry is leading the way in increasing the levels of autonomy used in the manned aviation sector, albeit with some funding (often EU) for new technologies.

18.2 The Government has made progress in the development of a much-needed Government-wide civil UAS strategy, including commission a series of public dialogues to provide members of the general public with information about UAS, in order to

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assist with the advancement of the technology and its practical application. Regrettably progress has stalled following the outcome of the EU referendum. Support for automated and autonomous technology development and industrial growth should be a feature of any future Government industrial strategy.

18.3 Upon resumption of this UAS strategy activity, the strategy should support industrial progress to maximise the socio-economic benefits of UAS application, as previously described, as well as providing an early public education programme to minimise the risk of entrenched positions, misunderstandings and over-reaction. However, the Government should not focus on a few narrow commercial applications, particularly those based on imported technology as this will not help the UK industrial base to achieve its growth potential.

18.4 The Government’s strategy should recognise the role of space technology in autonomy and must continue to support the UK’s leading role in the space sector as a necessary element in delivering autonomy advances. Specifically, space technology:

- Enables autonomous vehicles (cars, UAS, marine vessels);
- Contributes to the research and development of autonomy; and
- Benefits, itself, from autonomy developments in the wider economy

19. What are the implications of exit from the European Union for research and development and the autonomous vehicle industry in the UK? Are specific actions from the Government needed to support or protect the autonomous vehicles sector in the short term or after the terms of Brexit have been negotiated?

19.1 The EU’s main role in research, development and innovation is in defining priorities and allocating funding through the research framework programme; indeed, one of the best ways to achieve impact from research activities is to collaborate on projects across international boundaries

19.2 The EU’s research frameworks have provided an invaluable mechanism for building appropriately-funded EU-wide collaborative partnerships, encouraging projects and consortia from those targeted by national initiative, creating economies of scale and providing useful structures and links to facilitate international collaboration. EU research priorities and investment have been more stable than domestic budgets, which has helped nurture longer-term strategies that are less susceptible to short-term national political cycles.

19.3 The benefits of sharing in a large research programmes are considerable. Unless the UK is able to negotiate participation in EU-funded programmes, the UK will lose the multiplier effect. EU funding generates a beneficial effect in civil and general aeronautical research. The UK’s recently enhanced Research and Technology (R&T) budget is far short of the EU’s shared commitment.

19.4 The Government should avoid the creation of a situation where there is a disconnection from research networks and collaborators within the EU. The only way to have productive collaborations is for them to be funded. Collaboration with parties
outside the EU is current far more difficult than inside the Union due to the variabilities and often non-aligned nature of funding. Continued collaboration with EU partners outside the Horizon 2020 Framework is unlikely to be acceptable to Member States, and involvement is likely to require freedom of movement of those engaged in the research.

19.5 The EU has budgeted approximately €120 billion to support research and innovation projects from 2014 to 2020, of which a proportion was destined for the UK. Between 2007 and 2013, the UK had contributed an estimated €5.4 billion to EU research and development, and had received €8.8 billion in direct funding for research, development and innovation.

19.6 Horizon 2020, the biggest EU Research and Innovation programme with nearly €80 billion of funding, including €83 million for robotics and autonomous systems, available over 7 years (2014 to 2020), is aimed at supporting European economic growth and competitiveness through investment in research, removing barriers to innovation, creating a world-class science base and supporting international research collaboration.

19.7 Full participation in EU funding programmes would likely require full access to the Single Market and the acceptance of the freedom of movement, unless an alternative relationship can be negotiated.

19.8 Several countries outside the EU, including Norway, Turkey and Israel are eligible to participate in all Horizon 2020 projects as Associates, and Switzerland has more limited access to funding for some projects as a partial associate. The UK could pursue this relationship either through an EEA Agreement or under a bilateral arrangement but should expect to contribute financially (as Norway does) and lose some policy-making influence.

19.9 Without specific preventative action, Brexit will lead to the UK’s withdrawal from EU funded space programmes relevant to autonomous vehicles including:

- **The space element of Horizon 2020:** The UK will be unable to participate in this EU R&D funding framework;
- **Galileo:** The UK will be unable to participate in the programme itself, will lose access to specific protected features of the Galileo service that are of great interest to the autonomous vehicle community, and will lose knowledge, and influence on, evolutions of the Galileo service. The Ministry of Defence (MoD) decision to use the secure Galileo services announce in the Strategic Defence and Security Review 2015 will be compromised. The open navigation service will continue to be available to UK users;

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29 [Norway Mission to the EU: Norway’s participation in EU programmes and agencies](https://www.embassyofnorway.org/en).  
• **Copernicus:** The UK will lose access to much of the Copernicus (surveillance from space) programme, since it is largely EU-funded; and
• **Governmental Satellite Communications (GOVSATCOM):** The UK will lose access to GOVSATCOM, space surveillance and tracking, and other EU-funded space programmes currently being defined.

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