Innovate UK – Written evidence (AUV0037)

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1. Innovate UK is the UK’s innovation agency, a non-departmental public body sponsored by BEIS. It is the prime channel through which the Government de-risks innovation investment by business. Innovate UK is business-led. Our governing board and executive team is comprised of experienced business innovators and experts. We work with people, companies and partner organisations to find and drive the science and technology innovations that will increase productivity and exports and grow the UK economy.

2. We are working to:
   - accelerate UK economic growth by nurturing small high-growth potential firms in key market sectors, helping them to become high-growth mid-sized companies with strong productivity and export success;
   - build on innovation excellence throughout the UK, investing locally in areas of strength;
   - develop Catapult centres within a national innovation network, to provide access to cutting edge technologies, encourage inward investment and enable technical advances in existing businesses;
   - turn scientific excellence into economic impact and deliver results through innovation, in collaboration with the Research Community and Government; and,
   - evolve our funding models to explore ways to help public funding go further and work harder, while continuing to deliver impact from innovation.

3. In line with our strategy we operate across Government and advise on polices which relate to technology, innovation and knowledge transfer. We also support Government departments to become more efficient by supporting them in developing innovative solutions through harnessing the creativity that businesses can offer.

4. Innovate UK was established in July 2007 (as the Technology Strategy Board). We have invested over £1.8 billion in innovation, and have helped more than 7,600 innovative companies in projects estimated to add up to £13.1 billion to the UK economy and created an average of 7 jobs per company we have worked with. Our investment over the last 9 years has meant that every £1 invested has returned up to £7.3 GVA to the economy and created 55,000 jobs. The private sector more than matches that investment, doubling the power of public sector money. We work with nearly every University in the UK to stimulate the commercialisation of leading-edge academic research and innovation.

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5. Innovate UK welcomes the Committee’s inquiry. Set out below is our response to the questions raised by the Committee covering all modes for autonomous vehicles across land, sea and air. Firstly, it is appropriate to define terminology of vehicles and systems as applicable for each application:

a. **airborne** (remotely piloted autonomous systems (RPAS), Unmanned Aerial Systems [UAS] or Drones);

b. **land** (Autonomous Vehicles [AV], Driverless Cars and Automated Transport);

c. **water** (Autonomous/Unmanned surface vehicles [ASV/USV] or Autonomous/Unmanned Underwater vehicles [ASV/UUV], Autonomous/Unmanned underwater vehicles [AUV/UUV], also referred to as underwater drones).

6. It is useful to clarify our perspective on the terminology of **Autonomous systems**;

a. Different definitions exist for autonomous systems; in most cases the view taken for them is one of the external observer, and refer to systems that operate without a Human-in-the-Loop during the execution of their tasks.

b. While this definition can serve many purposes, it does not distinguish between systems that have “operational” autonomy, via some type of closed loop control with already embedded control laws or logic (which can also be called automated or adaptive systems\(^2\)), and systems which can “learn” and thus create their own logic, situation awareness, planning capabilities and their “own” laws or logic, thereby enabling “decisional” autonomy.

c. While the terms **automated** and **autonomous** tend to be used interchangeably, in order to minimize confusion we adopt the automated vs autonomous distinction herein; the automated systems do not include AI technologies like reasoning, learning, knowledge representation, planning or other higher level cognition, only the autonomous systems do.

d. Automation and autonomy can be thought of as comprising the two ends of a spectrum.

e. Current autonomous systems contain a set of cognitive capabilities allowing them to operate within certain situational boundaries.

f. The vast majority of current robotics systems are automated. Driverless/self-driven vehicles, that are often called autonomous vehicles, are also referred to by the corresponding industrial or regulatory bodies as ‘automated vehicles’.

g. Autonomous and/or automated systems may operate in the digital/cyber domain or, with the addition of sensors or actuators, within the real, physical world (e.g. autonomous robotics).

h. The reader should also be familiar with the SAE levels of autonomy. We feel that SAE levels 4-5 are the subjects in question\(^2\). This puts the current lane departure and emergency braking systems of the Daimler, Tesla Autopilot etc. out of scope.

i. It may be pertinent to clarify the distinction between vehicle component of the topic (for movement of people, goods, functional equipment, etc.) and the wider

\(^2\) [http://www.sae.org/misc/pdfs/automated_driving.pdf](http://www.sae.org/misc/pdfs/automated_driving.pdf)
service offering. For example the market value for robotics and autonomous vehicles for Nuclear decommissioning and Agriculture technology are heavily interwoven.

1. **What are the potential applications for autonomous vehicles?**

7. Potential applications for autonomous vehicles across air, water and land cover a broad range of market opportunities including but not limited to:
   
a. Infrastructure – monitoring, inventory, in-situ maintenance, Building Information Modelling (BIM) specific for site management and modeling. UAS/Drone services could support BIM by providing precise, digitised progress monitoring of a construction project, leading to more efficient construction management, enabling contractors to spot construction issues earlier. Also leading to safer sites.
   
b. Transport and Freight – movement of people and goods, off and on-shore delivery and logistics across all existing modes e.g.:
      i. Platooning of trucks – reduced energy use through aerodynamics;
      ii. Virtual train carriages - Including virtual coupling of train carriages leading to innovation in railway scheduling, signalling and demand response;
      iii. Platooning of passenger pods on railway tracks and busways (guided);
      iv. Small load delivery vehicles;
      v. Port to port delivery vehicles;
      vi. Motorways of the sea.
   
c. Disaster Response and Insurance – risk monitoring and assessment, incident response, monitoring, fraud prevention;
   
d. Media – filming, photography, location management, advertising;
   
e. Telecommunications – Network provision using High Altitude Pseudo Satellites (HAPS) and High Altitude Long Endurance (HALE) type drones;
   
f. Hostile environments - Offshore Energy and Nuclear – installation, maintenance and decommissioning;
   
g. Nuclear decommissioning - historically, the vehicle has been seen as a means of deploying the individual technology e.g. sensors, lasers, cameras. However, there is a greater push to develop fully integrated systems such that the vehicle and its payload can multi-task with the vehicle providing both the delivery to point of use and the power to operate the payloads, with the option to deploy a number of technologies simultaneously e.g. visualise, characterise, cut and remove. This has a:
      i. major role to play in reducing cost and time of decommissioning and minimising human exposure to radiation;
      ii. ability to carry wide range of payloads; and:
      iii. needs to be part of an integrated decommissioning system.
   
h. Agriculture – From small vehicles precision crop management, farm analysis, data capture, crop agronomy and livestock husbandry. Various aspects of crop storage and livestock housing could also be involved; from power delivery vehicles; the story is similar to the trend described in Nuclear. The “tractor” unit
will transport the implement capability – a seed drill or a cultivator – but will
trend towards fully integrated control and powering through appropriate drive
shafts. A plough can be an integrated part of the vehicle platform extending the
autonomous vehicle system to control lifting and rotating. Also sprayers large
and self propelled or micro precision sprayers using lasers, additionally a full size
combine harvester is a good customer for full autonomy;
i. Security and Policing – Monitoring, communications, crowd and incident
management;
j. Mapping, Surveying, & Construction – Site planning and management,
assessment monitoring and measurement;
k. Mining - deep mining, subsea mining, and recycling;
l. Emergency services and harsh environments - (particularly search and rescue
and fire-fighting), waste management and space exploration; and,
m. Innovate UK focused on civil applications and has not attempted to cover
defence (land, sea, air) focused programmes but it is a huge market so cannot be
ignored, especially in light of the US investment through DARPA and the
innovation spillovers expected as a result into civil markets. The UK’s dual use
technology exploitation programme (DUET) is a sign of the potential for re-use
of investment identified by the DGP (defence growth partnership).

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

8. Advantages include but not limited to:
   a. Increased safety and reduced road accident casualties (94% human error);
   b. Improved transport systems leading to increased productivity;
   c. Increased high value jobs leading to increased productivity per worker;
   d. Increased energy efficiency in vehicles;
   e. Increased vehicle asset utilisation;
   f. Reinventing of railway timetabling and demand management (virtual coupling);
   g. Removal of human workers from dangerous environments;
   h. Improved access to challenging harsh environments or dangerous areas;
   i. Safer and more efficient sea freight;
   j. Improved access to high quality data\(^3\) - UAS/drones enable lower cost services
      vs. manned flight and therefore game changing in service regularity compared to
      full scale rotary or fixed wing aircraft;
   k. Improved quality and frequency of monitoring;
   l. Faster reaction to policing, security and disaster management events; and,
   m. Lower cost and higher safety solutions to manned road, sea and air transport.

9. Disadvantages include but not limited to:
   a. Increased automation leading to loss of low skilled jobs;

\(^3\) Improved access to high quality data enabled by UAS surveillance and image processing is beneficial across
infrastructure management and construction, disaster response and insurance, media, telecommunications,
precision agriculture, security and policing, mapping and surveying. The improvement in access applies where
the need is for repeatable data sets, persistent monitoring and monitoring of situations not readily accessible
to humans.
b. Replacement of high value markets with lower value drone ones e.g. the civil helicopter market;
c. Cyber security concerns;
d. Privacy and safety issues (in UAS this may be driven in part by recreational users’ ignorance of, or desire to comply with existing regulation); and,
e. Incidents involving civil UAS incursions into restricted spaces and violations of privacy have occurred and get significant media coverage.

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

10. Yes, these will be different for different classes of system operating in different environments and controlled in different ways. This is a complex area and a one size will not fit all. To draw a road based metaphor imagine a road with a remote controlled car stopping frequently to deliver parcels, an autonomous car slowly surveying the surface, a person driving a coach full of people, and an articulated lorry transporting freight autonomously all having to interact, sense, and avoid each other and everything else around them. Now imagine this is hundreds to thousands of feet in the air over towns and cities with no, or little, physical infrastructure to guide the various systems.

11. Until recent times the UK had more UAS registered users than the USA. A testament to the excellent work by the civil aviation authority (CAA) in writing regulations. To maintain any advantage more work will be needed. Enabling of Beyond Visual Line of Sight (BVLOS) flight/shipping is key to the development of the UAS/ASV markets that require significant regulatory change; this is to be delivered by the Department for Transport by 2020. This will require the development of regulations in a number of areas including air traffic and shipping management, and sense and avoid certification.

12. Insurance is an area that will need a reasonable amount of focus to understand and legislate on the burden of liability for incidents involving the various types of vehicle and flight control types. BVLOS, automated, remotely piloted, and HAPS/HALE flights are different in nature and will require a different approach to insurance and liability. Whether insurance will be voluntary or mandatory for different system types in different flight situations and uses will also need to be considered. This may also require additional legislation relating to Police actions in the operation and potential misuse of these vehicles.

13. Aerospace legislation governing the certification of systems will also require revision. The range of systems will have different certification requirements along with a defined approach to system manufacturer certification to cover both platforms, as well as systems such as sense and avoid.

14. The UK was not a signatory of the Vienna Convention, which has given us a globally competitive advantage as a place to design, test and commercialise road-going vehicles. We can imagine only an 18-36mth advantage but with such a disruptive market with early mover and first to scale advantages this position should be maintained. C-CAV as part of the DfT are doing an excellent job in this regard to date.
15. A wider perspective regarding autonomy and liability will need to be resolved. The functioning of AVs will be a consequence of their programming / learning algorithms. Large-scale adoption, may generate legislative requirements for track back into software malfunction, such that the companies writing code (including framework code for autonomy) can be held accountable for its performance. It is not clear currently how this will be done, nor how the vehicle monitoring systems will gather the data that allows a distinction to be drawn between software, hardware, driver or even infrastructure error. These points are speculative although Microsoft has made the test case of liability back to software code during the House of Commons evidence session for robotics and autonomous systems.

4. What is the scale of the market opportunity for autonomous vehicles?

16. Market size predictions vary widely due to the relative immaturity of the market, forecasting accuracy and key technology enablers. However, future value of the platform vehicles can give some indication to the scale of the opportunity and therefore these market opportunities are really exciting for UK businesses:

a. Automotive - In 2014, more than 329 million commercial vehicles and 907 million passenger vehicles were in use worldwide. In 2014, more than 22 million commercial vehicles and approximately 68 million passenger cars were produced globally. According to a forecast by PwC, in 2017 a total of 102 million vehicles will be manufactured worldwide – The AV opportunity is fleet replacement and UK manufacturing, retail and servicing of vehicles and their autonomous control systems.

b. Aerospace - In 2015, there were almost 24,000 turboprop and regional aircraft, as well as widebody and narrowbody jets in service worldwide. General aviation [i.e. civil, non-commercial] includes over 362,000 aircraft flying worldwide today, ranging from two-seat training aircraft and utility helicopters to intercontinental business jets. In 2015, there were 2331 new shipments of general aviation aircraft, with total estimated billing of $24.12bn. There are 45,000 commercial passenger and freighter aircraft. Total new large commercial aircraft production over the period 2016-2020 is forecast to be 8,683 – Manufacture and export of propulsion and smart, connected and more electric aircraft systems plus their maintenance, repair and overhaul.

c. Cities and infrastructure industries - Supply, install, supporting infrastructure (connectivity, cyber security, control and optimisation algorithms, intelligent mobility and freight service models across transport modes).

d. Rail - The total number of new rail vehicles committed for delivery [in the UK] in the five-year period that commenced in April 2014 (Control Period 5, CPS) and in the early years of CP6 (2019 to 2024) is now over 4,500, with a capital cost of more than £7.5 billion.

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5 [Statista](https://www.statista.com)
6 General Aviation Manufacturers' Association
7 JetData
8 Long Term Passenger Rolling Stock Strategy for the Rail Industry, Rail Delivery Group, March 2016
e. Maritime - Over c80% of UK goods arrive via sea so maritime autonomous control systems are also of significance with 190,000+ ships of 100 GT and above in service, on order or under construction. Of the around 50,420 merchant ships trading internationally [as of Jan 2015], some 16,900 ships were bulk carriers.

f. Services: consultancy, insurance, etc. - Lloyds position us well for (re)insurance in auto/air, and the Register for shipping and rail.

17. Payload delivery in our end-user industries - mobile robots delivered to point of use on vehicular platforms – offshore energy, nuclear, agriculture, subsea are opportunities for UK robotics and artificial intelligence (RAAI) and less for the vehicle platforms.

18. Automotive - The 2014 report from SMMT/KPMG shows a predominant feature of the opportunity for CAV as economic growth in the order of $51bn per annum in the UK alone, which is driven to a large extent by increased productive time for workers whilst travelling. This time could equally be spent relaxing and lead to health benefits and reduced NHS costs.

19. However, taken from another perspective the value of the motor car in 2025 is expected to be made up of over 50% electronics. The current automotive electronics architecture designs with distributed electronic control units are unsuitable and therefore have unsustainable market share for fully autonomous cars. Therefore the market opportunity globally for electronics and software suppliers is trillions of dollars. The UK has a strong electronics and software capability but does not have a single tier 1 supplier of automotive electronics at scale. The disruption for automotive electronics is a major opportunity for the UK.

20. Extreme environments such as nuclear decommissioning, deep mining, sub-surface, subsea, outer space, and other challenging environments where it is unsafe to send human workers will benefit enormously. For example, an inevitable by-product of the rise of nuclear energy is the creation of a global decommissioning market, currently estimated to be worth £50 billion per annum by 2020. The total cost of nuclear decommissioning in the UK alone is currently estimated at £60 billion.

21. The latest market reports put the total addressable UAS market at around $127bn in 2015. Infrastructure - $45bn total addressable in 2016 and Precision Agriculture – $32bn total addressable in 2016, are assessed to be the largest addressable markets for UAS and both are examples that would complement and enhance existing high-value services rather than directly replace. It is important to view these market assessments in the context of the total market that UAS can address, should the technology and regulation allow. Much of the future market potential for UAS depends on changes to legislation including enabling BVLOS. For example, the current drone market for Infrastructure systems is $0.25bn against an addressable market of $45bn.

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11 [https://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf](https://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf)
In civil Aerospace the technology already exists to fly point-to-point on Autopilot without the need for any human input, only monitoring. Some members of the public on board commercial planes are able to tell through aircraft dynamics whether the autopilot or the captain has landed the plane, from the feel of the landing. The UK is well positioned, and the technology exists – the challenge is how we ensure the UK can leverage this across traditionally siloed modes of transport and large-scale public R&D incentivising funding streams.

5. **What has Innovate UK done in the area of Autonomous Vehicles?**

Sectors enabling the markets for AVs connect various part of the UK economy within Innovate UK’s priority areas and managed programmes including:

- Energy;
- Digital;
- AgriTech;
- Materials and Manufacturing;
- Transport (inc. Aerospace, Automotive, Rail and Marine);
- Aerospace Technology Institute R&D Programme;
- Enabling and Emerging Technologies; and,
- Infrastructure Systems.

Through Innovate UK’s Catapult network we have enabled the LUTZ (Low-carbon Urban Transport Zone) Pathfinder project. A pioneering CR&D project that carried early trials in public pedestrianised areas of fully-automated vehicles in Milton Keynes and has received world-wide press coverage, positioning the UK as a thriving hub of global business activity. Overseen by the Transport Systems Catapult, the project is using electric-powered two-seater pods that operate on designated pedestrianised areas. The pods are designed and manufactured by Coventry-based automotive innovation SME RDM, and equipped with autonomous control systems developed by the University of Oxford’s world-leading Mobile Robotics Group and rapidly commercialising in Oxbotica.

Innovate UK has, to date, delivered:

- Multiple sector (e.g. including Agri-tech) UAS related projects - 97 with grant funding of £24m to 100 unique organisations (49.5% of participants were SMEs);
  - The ASTRAEA programme was a total investment of £62m investment between 2006 and 2013 of which £12m was grant included above;
- Transport - Driverless cars city trials, 3 large consortia with grant funding of £19m to 38 unique organisations across public, private and 3rd sectors;
- Transport/Autonomous Connected Vehicles - C-CAV Collaborative Research & Development and Feasibility Studies – 22 projects with grant funding of £25m to 77 organisations;
- Maritime autonomous systems – Collaborative Research & Development – 8 projects with grant funding of £5m to 31 organisations; and,
- Adaptive Autonomous Ocean Sampling Networks (Natural Environment Research Council pre-commercial procurement) - 2 projects with grant of £2m to

**Notes:**

Numbers are in public grant value and are matched or exceeded by public sector investment in these programmes.
11 Feasibility studies and 4 prototype development contracts using the pre-commercial procurement framework (SBRI).

26. UAS is a significantly different market environment to driverless cars (CAV). There are technology crossovers but the technology and legislative challenges to the widespread uptake and deployment of UAS are complex and are being developed by the Civil Aviation Authority in the UK to accommodate a variety of different sizes and types of UAS operated in a number of ways. Civil UAS range from insect sized vehicles operating individually or in delivery swarms, to potentially commercial passenger sized vehicles and all sizes in-between. They can operate at a large range of altitudes though the atmosphere from a few feet off the ground to High Altitude Pseudo Satellites operating above 65,000 ft and into Space for exploration.

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

27. Digital infrastructure will be influenced by new demands on existing, and demands for new, secure communications networks that will no doubt arise from increased numbers of sophisticated autonomous vehicles.

28. There are different fields of thought regarding automated vs autonomous vehicles and the requirement for 100% reliable connectivity to enable some manufacturers chosen solutions. There is expert opinion (e.g. Google, Oxbotica, FIVEAI) that the most likely current outcome is that 100% reliable connectivity will add and enhance vehicular features, but will not be a requirement for standard operation of autonomous vehicles.

29. We wish to flag UK strengths in the provision of connectivity – linking in to 5G expertise, the LPWAN trials being undertaken by the Innovate UK Digital and Future Cities Catapults, and the planet wide connectivity that satellites can provide. The Satellite Applications Catapult are well positioned to provide the underpinning work, and marine is one of their priority areas.

30. There are competing theories on the need for connectivity in enabling autonomous operation of road vehicles. If a manufacturer decides to develop connected vehicles that require connectivity to operate autonomously then the communication networks in the UK would currently be a hindrance. The reliability and performance of current mobile networks is insufficient to support their widespread use. However, the pace of development of digital infrastructure technology is likely to outstrip that of vehicle development and so public sector procurement of infrastructure designs and innovation in service supply models.

31. UAS (Drones) may be able to have a positive effect on digital infrastructure through the deployment of HAPS/HALE drones to provide the infrastructure.

32. UAS physical infrastructure will remain largely unchanged, or at least changed minimally to allow for potential increases air traffic management load, a significant plus point is
that airborne systems are designed to interact with physical infrastructure rather than make use of it in the way land based vehicles have to.

25 October 2016