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Preamble

This evidence is based on my experience of autonomous vehicles and robotic systems gathered over the last 20 years in the agricultural sector. At HAU, we are currently designing and developing a complete range of new agricultural and horticultural equipment that will have significant economic and environmental benefits in how we interact with the natural environment by reducing the introduced energy (in all its different forms such as herbicides, fertiliser, fuel etc.) needed to support production agriculture and make food production more sustainable.

At HAU we have our own autonomous research tractor mostly compliant with ISO18497 (Safety of highly automated agricultural machines) and a range of smaller autonomous vehicles being developed for robotic strawberry harvesting, laser weeding, mowing golf courses, phenotyping and agricultural drones. We are just starting a new project to see if we can grow a complete crop with autonomous vehicles and without any person entering the field area.

In the context of this paper, I am extending the scope of ‘autonomous vehicles’ to include smart information systems, automation and robotics used to support them in crop production. If we have driverless cars and lorries on the road, we need provision for driverless tractors. Please note that I do not currently support the use of driverless tractors on the road.

Impacts and benefits
1. What are the potential applications for autonomous vehicles?
   The agricultural sector employs a lot of people to do simple repetitive tasks that can now be safely automated. A significant part of the cost of food production is paying a person to drive agricultural vehicles while carrying out simple field tasks or transportation of goods often on private land.

   Just removing the driver is only part of the solution. Once we have the catalyst for change, robotics and autonomous system methods can be used to reinvent agricultural machinery that not only operates by itself but can have enough embedded intelligence to ensure that only the minimum amount of energy is used to achieve the desired outcome, which we are now calling intelligently targeted inputs, e.g. laser weeding.

   Applications for autonomous vehicles range from simple field operations such as harrowing and rolling, through to the automated transport of logistics like strawberry crops or grain carting.
   The first commercial autonomous systems will probably be in the high value horticultural crops where the tasks are semi-skilled, time consuming and highly repetitive.
2. **What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?**

The main user benefits are likely to come from reduced input costs (intelligently targeted inputs) and the reduced need for cheap, often seasonal, labour.

One of the biggest benefits will come from the economics of employing less seasonal labour to carry out simple repetitive tasks. Seasonal labour is becoming more expensive and increasingly more difficult to come by. Some of these workers can be replaced by automation but not all of them as even the robots must work in a human supervised and supportive environment.

Many farmers are experiencing fears over the lack of cheap labour in terms of potential added restrictions embedded in the Brexit negotiations but the UK is in a good situation to be able to use and support high technology in the agricultural sector to not only compensate for this but to also make production more efficient.

Disadvantages of using autonomous vehicles in agriculture will be the inherent disruption to a set of mature businesses. It will be disruptive to the farmers as they will have to think about farming in a different way.

**Example:** Instead of damaging the soil each year with large tractors and then having to plough and cultivate to repair the damage, I now estimate that 90% of that energy can be saved by not creating the damage in the first place if we use small smart machines. If we do not damage it, we do not need to repair it.

Autonomous vehicles will be disruptive to the machinery industry as over the last 70 years we have seen a linear development of machines getting bigger due partly to the cost of the driver and partly due to economies of scale. Tractors have now reached their maximum size and cannot be made any bigger due to road and rail transport restrictions.

Autonomous vehicles will be disruptive to the service sector as farmers now have access to unprecedented data about their farms, fields, tractors, weather, soils etc., now commonly called big data. With the advent of drones and new tractor mounted sensing systems we can virtually measure every important crop parameter in real time on an individual plant basis.

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

Very little, because we are trying to understand the implications of a proposed system that is changing week by week. The need is clearly there; the economics seem to be justifiable in the longer term but it is unclear how the commercial system will be implemented.

4. **How much is known about public attitudes to autonomous vehicles?**

The popular media has shown a number of instances of robotic agriculture that have captured the public’s imagination in a positive way, such as Interstellar and Wall-E which
showed robots tending crops. This is countered by others that predict robots and AI will take over the world. In my experience most people believe that small smart machines helping us to grow food in an efficient and environmentally sensitive way is a good thing.

5. **What is the scale of the market opportunity for autonomous vehicles?**
   The scale of the market opportunity in the UK is a difficult one to estimate. The agricultural and horticultural sector is huge, but to what extent the robotic systems will penetrate is difficult to foresee as some tasks are clearly ripe for automation and others will always need people.

Creating an enabling environment
Research and development
6. **Is the scale of current and planned demonstration facilities for autonomous vehicles sufficiently broad and ambitious?**
   As far as I am aware there are no current or planned demonstration facilities for autonomous agricultural vehicles in the UK. There is one in Montpellier, France. At HAU we have our own test track and farm that we currently use for these purposes.

7. **Is the Government doing enough to fund research and development on autonomous vehicles, and to stimulate others to do so? Should it be doing more to coordinate UK actions?**
   There have been significant funds (£160m) input by the Government to the Agri-Tech Strategy that has funded 98 projects to date, including some of the projects mentioned above. Three new centres have been launched in 2016 one of which is the Agri-EPI Centre (Agricultural Engineering Precision Innovation Centre) which will give the high-tech agricultural sector very good facilities. One hub of that centre is based at HAU.

   There is the concern that as the Agri-Tech funds are now diminishing, there may not be a follow up scheme to keep innovation going. In my experience companies find it hard to innovate in disruptive technologies without Government help. I would strongly advocate the continuation of the Agri-Tech Strategy, within the Industrial Strategy now being developed by Government, to ensure that innovation in the UK is continually, and consistently, nurtured.

8. **How effective are Innovate UK and the CCAV in this area?**
   In my experience Innovate UK has been very influential and supportive in meeting the Government’s aims. We have had little contact with CCAV probably due to their focus on cars and ours on tractors.

9. **Is the environment for small and medium-sized enterprises (SMEs) working in this sector sufficiently enabling?**
   Due to the disruptive nature of these technologies and the hesitance of the big machinery manufacturers to get involved, I feel that the start-ups are more likely to exploit radically different technologies as they have no legacy baggage and are ready to exploit new paradigms. The Agri-Tech strategy has certainly helped many SMEs commercialise these opportunities.
Real world operation

10. **Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?**
   From the agricultural perspective we need wide area broadband technologies that can cover a farm. We already have good coverage from GPS and virtual base stations but for all the autonomous vehicles we envisage, it is important to be able to keep in touch, both from a user’s point of view (as the person responsible for the vehicle must be able to monitor and control it via WiFi) and from the requirement to move large data sets to and from the vehicle with telemetry.

   In the past we have modified the environment to suit the machines (big flat fields) but my philosophy is we should now make the machines smart enough to deal with the complexity of the real world.

11. **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?**
   There are many autonomous agricultural vehicles being developed around the world, but unlike the car sector there are no long term demonstrations in the agricultural sector as far as I am aware. I see demonstration as being the key milestone to their extensive deployment in the farming community. Once farmers see these technologies being used successfully, then they are more likely to invest, which makes it easier for the start-ups.

12. **Does the Government have an effective approach on data and cybersecurity in this sector?**
   I am unaware of any specific issues on this topic.

13. **Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?**
   In my development of the HAU autonomous tractor I have tried to adhere to all the current legislation and even go beyond it to embrace ISO18497.

   There are significant legislative changes needed to allow the use of new technologies. Many laws regulating the use of chemicals are defined in terms of how they are applied. Now we have intelligent systems that can apply chemical only to the leaf of the target plant, it makes the current laws redundant and restrictive. Many of the chemical companies have very good active ingredients that cannot currently be used as the method of applying them is defined in law. As the technology has moved ahead we need new regulations that can allow such beneficial changes.

14. **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?**
   In all my autonomous systems there is still a person in charge of the vehicle. They are not driving it and can carry out other non-related activities, but nevertheless they are responsible for the safe use of the machine and must be within 1km. In this manner the liability is clearly divided in two parts; that which is equipment supplied by the
manufacturer that must be fit for purpose, and that which is its use in the correct way by an operator. In my view this meets all current legislation.

It is not yet clear who takes responsibility when a mass produced driverless car has an accident.

**Wider governance**

15. *What does the proposed Modern Transport Bill need to deliver?*
   Inclusion of the use and regulation of autonomous agricultural vehicles.

16. *How effective is the UK’s education system in delivering people with the right skills to support the autonomous vehicles sector?*
   HAU is leading the UK in developing these technologies for agriculture, along with Lincoln University and Sheffield University. As universities we integrate our training with research. Many of our students are actively developing autonomous vehicle skills and even successfully competing at international level.

17. *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?*
   I feel that autonomous agricultural vehicles will have a bigger impact on agriculture than driverless cars will have on the road. My reasoning is that moving over to agricultural robotics gives the opportunity to redefine the tasks and operations we currently carry out and to use this change to significantly reduce the cost of crop production, reduce the impact on the environment, produce better cleaner food and hence improve the sustainability of the UK and world food supplies.

18. *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?*
   The EU has been developing a strategy to embrace robotic agriculture to such an extent there is a new call out, closing in Feb 2017. We are part of a consortium that will bid in this call.

   Brexit could limit farmer’s access to seasonal labour but some of these tasks and operations could be replaced by automation given suitable support.

   The UK government should recognise that these new technologies will give UK agriculture a new method to improve our food production and make us significantly more sustainable, but to do this the Agri-Tech Strategy needs to be continued and the research councils need to recognise robotic agriculture as being a key technology for fundamental research.

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