

Select Committee on Science and Technology

Corrected oral evidence: Autonomous Vehicles

Tuesday 1 November 2016

11.40 am

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Members present: Earl of Selborne (The Chairman); Lord Borwick; Lord Cameron of Dillington; Lord Fox; Lord Hennessy of Nympsfield; Lord Hunt of Chesterton; Lord Mair; Lord Maxton; Baroness Neville-Jones; Lord Oxburgh; Viscount Ridley; Lord Vallance of Tummel; and Baroness Young of Old Scone.

Evidence Session No. 2

Heard in Public

Questions 11 - 19

Witnesses

[!:](#) Dr Rob Buckingham FREng, Director, UK Atomic Energy Authority (UKAEA); and Professor Simon Blackmore, Head of Engineering, Harper Adams University.

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Examination of witnesses

Dr Rob Buckingham FREng and Professor Simon Blackmore.

The Chairman: I welcome Dr Rob Buckingham, from the UK Atomic Energy Authority, and Professor Simon Blackmore, from Harper Adams University. Would you like, first of all, to introduce yourselves for the record—we are being broadcast—and if you would like to make any introductory statement, please feel free to do so. Would Professor Blackmore like to start?

Professor Simon Blackmore: Thank you very much. My name is Professor Simon Blackmore, professor in robotics and automation at Harper Adams University, also in the new Agri-EPI centre being set up. My specialist area is in precision farming. I am director of the National Centre for Precision Farming but my technical interest is in developing what I now call robotic agriculture.

I was in the back just now listening to some of the questions, and the one point I wanted to make at the outset is that the work we are doing is not necessarily of benefit to the UK in terms of producing robot tractors. The benefit of our work is to make the crop production system significantly more efficient than it is at the moment. The benefit to the UK of introducing robotic agriculture is to make the whole crop production system more efficient and more sustainable, and so on and so forth. There are a lot of very good reasons for doing it. Fundamentally, that is the direction we are coming from.

Dr Rob Buckingham: Good morning. I am a director of the Atomic Energy Authority and I head up a new centre called RACE, Remote Applications in Challenging Environments, which received City Deal and Oxfordshire LEP funding. Prior to rejoining the Authority—I started there when I was 18—I have been an academic and also set up my own business, so I have been a bit entrepreneurial over the last 20 years.

The Chairman: Lord Vallance is going to open the batting.

Q11 Lord Vallance of Tummel: As a general starter, I wonder if each of you could outline how far along the road, or perhaps the off-road, the mainstream use of autonomous vehicles in your sector is, and what is the time-frame for deployment? Perhaps as a supplementary on that, could we both set up an industrial base, if you like, in the UK to manufacture the sort of kit you are talking about as well as helping UK agriculture?

Professor Simon Blackmore: As with a number of universities around the world, we have robotic tractors running around. Tractors have had auto-steer systems on them for many years. There is a very big difference between automatic steering and autonomous. Automatic steering is what I can get my students doing after a couple of weeks' teaching; we still do not have full understanding of autonomous yet. We are trying to work out exactly what that means and what is required. Technically, a lot of these things are available. I did hear, literally this week, that two autonomous

tractors have now been sold in the UK for delivery in 2017. I have not seen them, I cannot assess them and I do not know what safety systems they have in them, but I am in discussions regarding them. We have demonstration of these vehicles running in controlled situations. As Lord Fox mentioned a moment ago, some of you may have seen in the *Times* today there is a spread on what we now call the “Hands Free Hectare”. For the first time in the world we are now going to try to grow a commercial crop in the UK without anybody going into that hectare. We will do that through robotic tractors, robotic harvesters, drones and whatever else it takes to achieve that. Technically we are nearly there, and I am sure we will discuss the next stage in more detail as we go through, but there are a lot of other issues as to why we are not commercialising it right now.

Dr Rob Buckingham: We are at a very early stage in this technology. It is going to make huge strides over the coming decades, so we should not see ourselves as being out of any game; we are in a good position to make the most in this field, and we have to work out how to do just that. In the nuclear field, in petrochemical markets, in other challenging environments, we can see that there are real opportunities for this sort of technology to help us. This is not a replacement; this is an extension of human capability we are working at, so that we can work in challenging environments generally. It is very early days. If we look at, for instance, decommissioning at Sellafield or decommissioning in the North Sea, all these things would benefit from more efficient processes and tools. It is early days and all to play for.

Q12 Lord Hunt of Chesterton: It is very interesting to hear what you are concerned with. Can you describe the environmental factors that will limit it? I am a fluid dynamicist, so the notion of commercial shipping dealing with very large waves without anybody on the ship seems quite remarkable. Presumably in your dealing with these nuclear reactors and so on they are going to have special features that will make having autonomous systems quite tricky. Can you generalise the whole approach that, as it were, the system will apply to all kinds of applications?

Dr Rob Buckingham: You cannot generalise. That is one of the big differences between what you were talking about in the last session on driverless vehicles and doing things within an industrial facility. Those industrial facilities are optimised for safety, for productivity, whatever is required for that thing to function efficiently. It is very difficult to generalise when you come to the specifics. However, there are lots of very broad principles which are highly relevant. It is important to note that cars are the first robots. I look at the tech coming out of the autonomous vehicle piece as being highly relevant to anything that is happening in the challenging environment space. All the artificial intelligence and machine learning work that is going on—all the work on sensors, liability and all the other issues you talked about—is highly relevant to anything that is working in challenging environments. A key point here is that we must not make a disconnect between what is going on our roads and what is going on in our industrial, defined spaces, because that is where you start to get the bleed-through with technology transfer, and that is where you can start to build a viable ecosystem in the UK. These examples of extreme

environments where people cannot or should not work are going to be users of this underlying technology.

Lord Hennessy of Nympsfield: Were the robots we developed for decontaminating the Windscale piles the world leaders? Is this where the pace was made for the whole business of AI and robots?

Dr Rob Buckingham: The nuclear sector has always required robots because of radiation. They have generally been robots operated by people, so we talk about remote operations: people with long tongs, or whatever, so you separate the person from the hazard. We are on a journey of moving from remote operation to remote oversight. We do not need to take people out of the loop completely; what we want to do is use the human brain and make sure that that is part of the loop, but enable the tools that those people are using to be more efficient and to get on with more of the job autonomously. That is the transition that is going on. It is not as dramatic as the transition in driverless cars; we are adding capability to those tools so that they work better.

Lord Fox: In its heyday in the North Sea, the subsea industry and ROVs were, if not the leading, a leading industry. Taking it from ROV to the next step, as you have just described, for subsea, is there crossover between what you are doing and what the subsea industry is doing? Is there a future there as well or has that now gone?

Dr Rob Buckingham: No, there is absolutely a future. Unfortunately, David Lane, who was meant to be here today, has been stuck in fog. He is the expert on underwater stuff and launched a company that was sold to Subsea 7, et cetera. Absolutely there is crossover. The challenge with robots is you have to know where you are and what is around you, and then you have to decide what to do. It is the same challenge, whether it is a car, a tractor, an underwater vehicle or a flying vehicle. There is lots of bleed-through, and one of the ways in which the UK can win in this area is by ensuring that we do not become siloed. We are talking around things such as assets—RAS assets was a word we used in the UK RAS strategy in 2014—the point being you need a farm, you need a hospital, you need Schiehallion, you need a nuclear power plant where you are testing these things for whether they work. You are then trying to share knowledge between those areas so that you make progress faster. We do not have enough people in every single sector to win in every single sector, so we have to work smart to maximise the gain. We should perhaps come back to the question of how you make money out of all of this, which I think is the most pertinent issue in this.

Lord Maxton: Professor Blackmore, obviously you are more advanced in agriculture in automated vehicles than anywhere else, but at some point or other most agricultural vehicles have to go on the public roads. How do you get round that particular problem if you are ahead of the game in automation?

Professor Simon Blackmore: I mentioned in my written evidence that at the moment I do not currently support the use of robotic tractors on the road. Cars and lorries are designed to go on the road, the tractor is designed to work in the field.

Lord Maxton: If you are moving an automated tractor you would have to put it on

some form of—

Professor Simon Blackmore: It would either have to go on to a trailer, or something like that, or be driven in the normal way.

Lord Maxton: That is fine if it is a tractor, but if it is a combine harvester?

Professor Simon Blackmore: Good question. There are still issues here. As I say, these machines are designed for off-road use so we need to be very careful how they are being used on the road, and transport is certainly a major issue.

Q13 Lord Mair: In a previous session I asked a question about test facilities. My question to you is: are the Government doing enough for your sectors? What are your views about the need to invest in world-class test facilities, as far as your sectors are concerned?

Dr Rob Buckingham: My view on this is that test facilities are absolutely essential, but we must come back to how you convert that into jobs and growth. So not yet, but there are discussions around some major investments in this area, and if there are major investments announced then some of that money should certainly go into test facilities. This is about opening up places and spaces that are then used to test not just the technology but everything that sits around it—the insurance, finance and all of that. Are we doing enough? Not yet. That does not mean that we are behind the curve. Now is a very good time to make a serious investment in this area.

I will give you a couple of examples. In the nuclear space we should be doing something around identifying a building, for instance at Sellafield, which we take down using the latest technologies. On my site we are now running autonomous vehicles around it. This is a government-owned site which has 10 kilometres of roads inside a fence. Oxbotica, the company you heard mentioned earlier, is using that site to do its pre-road trials. That is a site with 2,000 people and that is a really interesting mix of ingredients that allow you to start testing the vehicles, the people and everything that sits around it. Those are two examples. If David Lane were here he would say, “We should be identifying something in the North Sea which, instead of taking it apart, we use to develop these innovative techniques”. We need to make sure that we put some of our money into the innovative part as well as doing the day job.

Lord Mair: Do you think the Government need to put a lot of money into such test facilities? Is that what is needed now?

Dr Rob Buckingham: I would make sure that part of the money going into infrastructure is for smart infrastructure. You can apply this to roads, to rail, to nuclear systems, or whatever you like. If we are just using that money to reinforce what we have done before we are not going to learn. We have to be willing to take some risks and ensure that some of that funding is used for the innovative piece. Government procurement is a very important tool to get traction in this area.

Professor Simon Blackmore: From the agricultural sector, every farmer I have spoken to has volunteered his or her farm when we are talking about laser weeding.

We do need this opportunity to demonstrate equipment more than we are getting at the moment. I mentioned the “Hands Free Hectare”, which is the first start of this. The disruption that robotic agriculture will cause within agriculture and within the machinery sector, the advisory sector and so on, is difficult to overcome by itself. It requires a lot more demonstration before people will be convinced, because it is so disruptive. Therefore, I believe there is a role for the Government to be able to fund the development of this disruptive technology to make it clear to all those other potential investors that there is a significant opportunity here for them.

- Q14 **Viscount Ridley:** In contrast to vehicles on roads, a lot of the things you are talking about here are either wandering around in the same space or fenced in with a geofence, or something. I would like to get an understanding of how different the global versus the local awareness of the technology has to be. What are the differences here? Also, we have heard talk of swarms, much smaller vehicles, doing things. One of the points that Harper Adams made in your written evidence is that the only reason tractors are so huge is that you are trying to get the maximum output from one man, and that you could go back to lots of smaller vehicles operating co-operatively, not competitively. Can you give us a picture of how different that world is from what we are talking about on the road?

Professor Simon Blackmore: When we talk about swarms, quite often we are talking about reducing the intelligence within each individual and allowing them to work together, as a bee or wasp, and so on, will do. We do not necessarily need to go to that level because each machine can be controlled by itself anyway; that is what we are doing now with these machines. We have the ability to allow multiple machines to work together: this machine will go down that row; that machine will go down that row; and make sure they do not meet each other down the same row. We have the capability to co-ordinate all these machines together. In doing the tasks we have already identified, as with any automation, we are looking at the highly repetitive, semi-skilled labour, and this is the easier-type situations we need, and we do not necessarily need advanced machine intelligence to do this; it is what we call deterministic. The other side of it is being able to be reactive. A lot of the operations are in semi-controlled areas, a field, and the public normally are not there. We can have fairly straightforward behaviour and safety systems to allow these machines to work by themselves without having to rely too heavily on great levels of artificial intelligence.

Viscount Ridley: You can already buy a lawnmower that wanders around your lawn and does not go outside an area. Is that a model for the way these things operate?

Professor Simon Blackmore: No, because you would not want to plough your field randomly.

Viscount Ridley: A good point. Why not?

Dr Rob Buckingham: In my field, I am interested in finite numbers of devices that communicate. We want to use mobile vehicles with drones, with arms; the right tools to get the job done. This is a challenge-led issue; we are solving an engineering problem by using these tools to make the place as safe as possible and work as

efficiently as possible. It is a very pragmatic approach. It is very focused; it is very controlled. We are making a managed assessment of the risk/reward.

Lord Hunt of Chesterton: One of the most major scientific challenges is perhaps not climate change, as Lord Ridley might agree, but dealing with our huge nuclear waste, where we may have waste lasting 10,000 years or more. One of the ways of doing this, of course, is transmutation, and transmutation has been made possible with fusion and fission systems. With your autonomous, much more complex systems, it will be of tremendous economic advantage, presumably, if we use this technology to get rid of, and possibly make energy value out of, all our nuclear waste over the decades to come.

Dr Rob Buckingham: Certainly we have some very valuable materials that we do not quite know what to do with. The robotics part of it is absolutely essential. Our futures will become increasingly nuclear, that is obvious.

Lord Hunt of Chesterton: Could you put an economic price on that? Let us suppose you could find a way of, as it were, using our waste. As you say, some of them are quite exotic materials. Obviously, people would sit up and take notice.

Dr Rob Buckingham: That is probably a topic that is not quite the same as this one. Fourth-generation nuclear power solutions and the like is probably not an area I am going to go into today. You are absolutely right. My point is that the robotics part of making that toolkit work is an essential component in making this whole sector work. As we think about the latter half of this century, we will have to have the robotic tools which will deal with these very unpleasant materials. Equally, we will want to use those tools to go and explore space and the oceans. All the places where humanity is limited at the moment will be the places that we start to gain access to in the latter half of this century and into the next. This is about enabling us to explore and make the most of these new places and spaces.

Baroness Young of Old Scone: Correct me if I am wrong, but the impression I am getting is that there is a fair amount of oomph globally and in the UK around developing autonomous road vehicles and that there is quite a strong government programme, a lot of interest and it is moving at quite a rapid pace. You are saying that we are at the beginning of this in your sectors. Do you think that enough government attention is being paid to your part of the picture? If you could have more government attention, what would it be?

Dr Rob Buckingham: Ask me in six months' time. There is a lot of stuff going on behind the scenes, and we shall see what happens. If in six months' time a lot more is not happening then I will say that we are not doing enough.

Baroness Young of Old Scone: What would a lot more look like?

Dr Rob Buckingham: We would both say—I do not want to put words in your mouth—that we would want to accelerate the pace in these areas. The reason why the driverless car tech is taking off is that, in some respects, it is relatively easy because roads are flat. In other ways it is really difficult because it involves interaction with people. In our environment, you take those people out of the way

and that reduces a lot of the concerns, and you have a different attitude to health and safety and all those sorts of things.

In some ways, our challenges are more technically challenging; fields are not all the same, nuclear reactors are not all the same. We need the tech to get to a mature level where we can trust it. We have just completed some work with the Lloyds Register Foundation, and there was a Foresight report on robotics and autonomous systems. A key word that came up in that was “trust”. This is around people who are investing to get a return on their investment, whatever that means [however measured], and they have to trust those robotic tools so that they get that return. You are building the evidence base on which to do that.

Baroness Young of Old Scone: When you are looking for government support is it more money for research, is it bringing industrial and research interests together, is it more work on the regulatory system? What is your Christmas shopping list?

Dr Rob Buckingham: I would put it in the innovation space, so we need to be making more from our research. That does not mean stopping the research, it means making more from the research and making sure that gets into industry.

Professor Simon Blackmore: From the agricultural sector, when I compare the two sides, I see that we have cars before they have been robotised and cars after they have been robotised and they are still doing the same job. But in agriculture the whole mechanisation system will now change, and we are only starting to see what those requirements are and coming up with some of the prototype machines. From my point of view, we have a number of Innovate UK projects on the go at the moment, which we find very successful. The Government were very good with the agri-tech strategy; but now that that is coming to an end and it is all being pooled, my concern is that whereas we had that amount of money pointed in this direction and it stimulated the growth and interest—without that money this would not have happened—that money is now coming to an end and being pooled with everything else.

Lord Hunt of Chesterton: Do you mean pulled or pooled?

Professor Simon Blackmore: Pooled. It is being joined into the general funds. Well, it is being pulled because—

Lord Hunt of Chesterton: Being pulled has the connotation of being stopped.

Professor Simon Blackmore: The agri-tech strategy funding is coming to an end now, and any further funding is in a more general area. I would like to be able to see robotic agriculture being a named area that then will be recognised equally with medicine, transport and all these other things because the opportunity for British agriculture is so huge. If the funding were to slow down or stop then a lot of this innovation would slow down and we would not overcome the disruption. It is essential that this money is kept going to allow us to get to the point where every farmer can see the benefit of it or we can get more companies involved in making these machines.

The Chairman: The Government are expected to formulate an industrial strategy.

Do you expect that strategy to be as specific as to refer to robotics in agriculture?

Professor Simon Blackmore: From what I have seen, no, but I would advocate that certain areas would be either priority or ring-fenced. As we know, agriculture is sometimes seen as the poor cousin; medicine or transport are seen as the big industries, and agriculture tends to follow along afterwards. I would like to see this type of research brought up to the same level of priority. Now that we have started the ball rolling, I would like to see it continue for a few more years. I am sure then we will get the industry to buy into it fully.

Q15 **Baroness Neville-Jones:** I must say if an industrial strategy is going to be worth anything it needs an implementation plan that indicates what we are going to be doing, as distinct from where we think we might be heading in a few years' time. Your point is extremely well taken. Could I revert briefly to the question of regulation? You mentioned the word "trust", which seems to me quite important in this world. The environments we are talking about here are not so disrupted by unreliable humans wandering around the place. On the other hand, you said that technically it is quite challenging. What is the role of regulation in the areas we are talking about here? Is it more technical regulation or is it the context in which these robots are used? How important is that in the cycle of development? Do you do the trials first and then draw the regulatory consequences, or do you have to have a regulatory framework before you can do that? How do you see that sequence developing?

Dr Rob Buckingham: Historically, the regulations have grown up around the fact that we are protecting people: the people who are doing the work and the people who might be affected in some way. One of the issues with robotics is that we need to avoid requiring the robots to have the same amount of regulation that a person doing the same job would. That is an interesting challenge. What I am saying is that robots are way more expendable than humans. That is an interesting one because many industries are built up on the basis that a person is going to be doing that job—an inspection and maintenance job, a non-destructive testing job—and therefore everything is built up around what a person is able to do and therefore what is acceptable. If a robot is able to do more, how does that change the regulatory environment? There are some really big issues around all of that.

Moving from people doing everything to robots doing part of it is a bit of a transition. It is not so much of a problem within these sectors because they are well managed and self-contained, so to speak. There are regulatory frameworks which are very well established, so we need to amend those regulations a little, but that will happen over time. I do not see a big issue with that.

Baroness Neville-Jones: You would go ahead with trials?

Dr Rob Buckingham: Yes.

Baroness Neville-Jones: In the absence of knowing precisely where the regulatory environment is going to end up?

Dr Rob Buckingham: For instance, we have principles such as ALARP. You are trying to minimise the risk, and you would still have detailed safety cases and HAZOP assessments, and all sorts of things like that, to make sure that you were behaving in a safe way.

Baroness Neville-Jones: Can that be UK based or does it have to be international?

Dr Rob Buckingham: No, UK and international.

Baroness Neville-Jones: You have both?

Dr Rob Buckingham: Yes.

Professor Simon Blackmore: In the agricultural sector there is a draft ISO standard 18497 for highly automated agricultural vehicles, which I think has given us some very good guidelines. There is a corollary in terms of regulation, and that is when we are using herbicides and pesticides at the moment, the legislation is tied up in terms of how it is applied.

Baroness Neville-Jones: Process.

Professor Simon Blackmore: But now that we have the ability to use machine vision to recognise 26 different species of weeds, we then have the ability to put chemical only on to the leaf of the weed, so 100% of the chemical goes on to the leaf of the weed. We are also getting the issue where a lot of the weeds are now herbicide resistant but the chemical companies have a lot of active ingredients that they are not allowed to use now because they must not put them through a 36-metre boom sprayer. As technology moves ahead, we have to allow those active ingredients to be used when they are applied in these new ways. There is a whole set of other ramifications from this type of work that needs to filter out to be able to cover the agricultural sector.

The same with the drones; we are testing for spraying chemicals with drones, but we are working with the Civil Aviation Authority and the Chemicals Regulation Directorate, and they are very supportive of doing this. Whatever legislation we come up with, it must not embody the particular technology we have now because the technology is always changing so quickly and that then stops the innovation. We need to deregulate these areas to allow this innovation to flourish.

Baroness Neville-Jones: Or you need a different approach to regulation which is more outcome-based.

Professor Simon Blackmore: Yes, exactly.

Q16 **Lord Hunt of Chesterton:** You are touching on this question, but do you feel on this whole development of autonomous-plus applications we have the right training and skills of students? Are universities moving in the right direction? Obviously, you are talking about capabilities stretching out for decades, and universities last hundreds of years. It seemed to me, from the way you were describing it, that there is a need for quite a strategic view of how this fits into the educational/university model.

Professor Simon Blackmore: As a university we do this research and the training, so our students learn how to make a tractor robotic, and so on, as part of their

undergraduate degrees. That capability can then run all the way through. The issue is how do we understand the disruption of this new system? As I have said on a number of occasions, using robots in agriculture is going to be very disruptive. We need to retrain the farmers to learn how to use the machines in a better way. We need to upskill the current tractor drivers to become robot operators.

There is another, adjacent part to this, and I do not know whether it will come up in questions so I would like to raise it now. Many of the farmers dealing with high-value crops at the moment are using seasonal labour, and with the advent of Brexit and possible limitation of seasonal labour a lot of the farmers I am speaking to are very nervous about this; their business is predicated on this. But there is this opportunity, coming back to, maybe, the funding and the opportunities within the UK, to replace significant numbers of seasonal labour with highly automated machines. Some of the work we are doing on strawberry harvesting and other types of harvesting are lending themselves—

Lord Hunt of Chesterton: The level of skill and knowledge will have to be raised considerably, will it not?

Professor Simon Blackmore: I do not think you need a PhD to run the sorts of robots we are developing or envisaging.

Dr Rob Buckingham: There is a massive transformation going on here. We talked about robotics being the arms, legs and eyes of the internet. We are at an early stage of major change, where artificial intelligence and machine learning are applied to all sorts of tools which will enable us to do a variety of tasks in different ways across a whole range of sectors. That means that we are going to have to have loads more STEM-educated people. There is no doubt, if we are going to make progress in this, we need to massively increase the number of software and electronic engineers, et cetera, across the piece. The whole STEM piece is going to become absolutely essential because so many of these jobs will start to use this new generation of tools, these new smarter tools.

Lord Cameron of Dillington: I was an early user of ground source heat pumps, and one of the problems was that it was almost impossible to get a local plumber to sort the blooming thing because there were not the technicians available. Are you, within your different fields, collaborating to make the technology standard so that different people can be used to mend and service your different equipment in all the different fields where they will be used? Can the same person apply themselves to servicing both sets of equipment?

Dr Rob Buckingham: Not yet. We should do.

Professor Simon Blackmore: As always, we all want to have standards but I think it is way too early for that, at this stage.

Lord Fox: To be clear, coming back to the skills side, there are two sets of people: what I will call the traditional agricultural workers, and then the people you are describing who will service this new industry. First, is there any crossover between these people, or are we essentially leaving that group of people behind and saying that there will be no more traditional agriculture jobs—and what is the impact of

that? And are we expecting the new agricultural workers to be the software engineers and the electrical engineers of the future? Where is the crossover between those developing this technology and those who will be out in the field, literally?

Professor Simon Blackmore: To be honest, I think a lot of that exists already. When you think about the new combine harvesters, they have 18 computers and they are all running with CAN buses, so that is already out there. The manufacturers are then having to train the technical staff not necessarily to reprogram the computer but to take the black box out and replace it with a new black box when it is not making sense any more. Regarding the ability to deal with more intelligent vehicles, certainly in my view the agricultural machines always need to be in communication via Wi-Fi to be able to transmit data backwards and forwards. Again, in my system, although we talk of robotic—again, this is different from the vehicle area—and consider that that is taking the person out of the system, we are not doing that, we are taking the person out of the vehicle. The idea is that I could perhaps be sitting here or in my university talking to you and then I have a smart phone and there is a heartbeat going backwards and forwards to the vehicle to show that I am in charge of that vehicle. I am not quite sure what the on-road sector is going to do when there is an accident, but it is the operator's responsibility not to send it out in a hurricane or when it has flooded or it is snowing. A person has to make some local decisions about how to operate the machine.

Lord Fox: It is not self-deploying, or anything like that.

Professor Simon Blackmore: Exactly. It is just that you do not have to have a person hanging on to a steering wheel any more.

Lord Fox: I understand.

Professor Simon Blackmore: There are these different roles, but I do not see any reason why we cannot have the best technologies in the world being embedded within these machines. You do not necessarily, as I said before, have to have a PhD to be able to run it, you just need a new set of skills to understand the capability of the machine and how to make sure it is operated in the correct way.

Lord Fox: I heard yet another cri de coeur from Dr Buckingham for STEM people. We hear it in lots of other fields as well, so that is clearly something you are all shouting for.

Professor Simon Blackmore: We always need good people to develop these things, yes, definitely.

Q17 Lord Oxburgh: We have been talking about regulation, and of course the question of legal liability follows on from that. Dr Blackmore, you have partly answered that because, with your smart phone giving you the heartbeat of the machine, you are responsible. We are talking here about a great range of possible applications for these technologies. It seems to me that the question of liability and responsibility is, in fact, going to differ in each of these, whether one is looking at drones, at agricultural vehicles in fields or at underwater activities. It seems to me, and I do

not know whether you would agree with this, it is the person who deploys the robot to do a particular job that carries the ultimate responsibility.

Professor Simon Blackmore: To be honest, it is a balance between the two, and the way that we have designed our autonomous tractor is to be able to work in exactly the same way that we have products now. Some of the liability of our cars is within the realms of the manufacturer and some of the responsibility is with us in operating them. It is exactly the same scenario with autonomous vehicles.

Lord Oxburgh: If we stay with your autonomous agricultural vehicles for a moment, it seems to me that there are always going to be situations in which they get stuck, for example, in heavy ground. Are people going to have to dig them out, and make them happy again?

Professor Simon Blackmore: We have these strange, science fiction thoughts going round our heads that robots are going to take over the world. I am afraid I cannot see that happening; these are pretty dumb machines. You only have to kick it and it stops; you only have to pull a cable out and it falls over. The robots we are developing now are very useful in that they can do a particular niche task, but they have to run within a human-supported environment. The person who is in charge of the machine has to be able to refuel it, service it, pump up the tyres, dig it out of the mud—all these things. Nevertheless, it can still have a good impact on the tasks we are trying to achieve.

Dr Rob Buckingham: In some environments that human intervention becomes impossible, such as in space or, indeed, in nuclear environments. There you have a different set of challenges, where you have to think about how to operate with zero intervention. That is a real challenge because you have to make sure your systems are highly reliable but also recoverable—because they will fail—and self-recoverable. In nuclear spaces, those are the very hard questions you have to address: when things go wrong what happens when you cannot get in there to fix it? It is hugely challenging because you have to think very carefully about the design of the system and everything that flows from it. It does mean that you are very challenge-led, so it is a great area for finding out what is possible; we are able to push way beyond where we are at the moment. That is what we hope.

The Chairman: We have probably just about come to the conclusion. I began to think I should have declared an interest which I have not, and that was as a fruit grower.

Lord Cameron of Dillington: I should also declare an interest as a farmer.

Lord Hunt of Chesterton: Do other organisations have some input or steering? For example, does the International Atomic Energy Agency now have a panel or a group that is, as it were, producing long-distance targets for how we will use autonomous systems to deal with nuclear waste?

Dr Rob Buckingham: I have three days with the IAEA next week or the week after, so we are absolutely starting to think about those things in detail. The other thing is we must set up this RAS—robotics autonomous systems—leadership council. That is what the House of Commons Select Committee called for, and this is one of the

ways where we can start to co-ordinate all these efforts, both nationally and internationally. That group is going to be key in this area because it is going to pull so many different strands together. Without that co-ordination we will remain completely siloed and we will underperform.

Lord Hunt of Chesterton: The Commons is producing an all-party group on artificial intelligence. That is different to what you are producing?

Dr Rob Buckingham: Artificial intelligence in robotics is the software you will probably use to make your robots more efficient. Artificial intelligence, as algorithms that solve discrete problems in the digital space, is a separate field, but they overlap.

Baroness Neville-Jones: I think this is potentially a huge topic, but can I have a rapid reaction from you? Nobody has mentioned cost in all this business of transition. Is the capital cost of these robots going to be a barrier to their adoption or not?

Dr Rob Buckingham: When you look at a driverless car, the tech associated with the autonomy piece is only going to be a few hundred dollars, because of volume. You have some software and some sensors—they may even not be new sensors and you may end up using parking sensors—so the tech is going to end up being yay big and not very expensive. That is why it is important that these sectors which have mass volume pull this stuff through to the market. If we tried to do that in, say, nuclear or in space, you can add a couple of noughts on to the cost of these things. A lot of the tech will become much, much cheaper over the course of the coming years and decades.

Baroness Neville-Jones: Your robotic tractor is not necessarily going to be significantly more expensive than your existing one?

Professor Simon Blackmore: Farmers invest huge amounts of money, hundreds of thousands of pounds, on tractors and combines already, but quite often with these operations the most expensive part of it is the person sitting in it. Therefore, by being able to do things in a radically different way using a lot less energy, doing things faster and smarter, although the base machine is expensive now, prices will come down. The machine costs very little but it is usually the sensors and the systems on it which cost the most amount of money.

Baroness Neville-Jones: When you take the human fruit-pickers out and you employ a machine where you have not employed a machine previously, what is the situation there?

Professor Simon Blackmore: We can look at the economics of replacing seasonal labour with these machines, and it is something we are looking at now. The farmers I am talking to believe intuitively that this is going to be a good thing and we need to do this, because it is more than just the cost; it is the risk of not being able to get the labour. That is the major factor. As we know with all these technologies, as they become more mature the price tumbles. We are talking about research machines at the moment, but once we get into mass production I believe that there is a significant opportunity for the UK in the agricultural robotic area. Companies producing robot tractors now do not have joined-up thinking; this is just taking a

person off, not going to the whole hog and being able to come up with a complete system. I believe the robots we are talking about now are worldwide commodities, so the same robot would work in South America, North America and northern Europe. In northern Europe, referring to an earlier question, we have the technology to support these things. It will not be the big tractor manufacturers that are going to produce these things, because they are too linear thinking; it will be the start-ups. There is an opportunity—

Baroness Neville-Jones: Or a data company.

Professor Simon Blackmore: —to get this going in the UK and then being able to produce millions of these things that will then be exported around the world.

Q18 Lord Vallance of Tummel: Dr Buckingham, you touched on the leadership council idea. I was going to ask Professor Lane about that, had he not been fog-bound, because it is in his written submission. He says, quite clearly, that the existing structure of looking out for all this is not quite up to it and it needs something rather different, and that perhaps a catapult centre is not designed for this. Could you tell us a little bit about the leadership council? Specifically, is it going to look at the commercial aspect as well, or is it just technological and development?

Dr Rob Buckingham: No, it has to look at the commercial aspects, absolutely. We have to make some money out of this.

Baroness Neville-Jones: Hurray.

Dr Rob Buckingham: The problem with RAS—robotics and autonomous systems—is that it is a general purpose technology which has many applications across lots of sectors. As we are pointing out, it changes the way things happen as well as just being a thing that you sell. The interaction of driverless cars with the way we design houses would be an example. There are huge and very widespread impacts in all these sectors. The challenge here is how do you decide where to invest your finite amount of money? Where do you get your best return? How do you migrate great research into industry? Our view is that a leadership council should be a Minister with money convening. That is the power. You should also have a co-chair who is an industry figure—probably from one of the large multinationals—who sees real potential in a particular area. You would then have a group of 10 to 20 people who are predominantly industry but you would have some academics and people from the Ministry of Defence, the Atomic Energy Authority and others like those involved as well to represent all elements of government. It has to be a group which is focused around the economic impact.

Lord Cameron of Dillington: I was going to ask Professor Blackmore who was going to build his first commercial mini-tractor. Where is the money coming from? Last time we spoke, you were a bit concerned that the only interest you seemed to be getting was from China. Is that still the case? How are we going to commercialise all your inventions?

Professor Simon Blackmore: Due to the agri-tech funds over the last few years, a lot of people from outside the agricultural sector are now looking into this. With the

facilities we are getting within the new Agri-EPI Centre at Harper, along with Cranfield and SRUC as well, we are now getting significant private money looking at this area. Whether that is enough to make it happen or not I do not know, but I think it is only going to be the start-up companies, which have no legacy and no vested interests in the past, that are going to adopt these technologies fully. The tractor manufacturers have such a legacy and their existing business models that they are very reticent to adopt something that is going to disrupt their business.

Lord Cameron of Dillington: I would be very surprised by that because, going back to my earlier question about servicing these machines around the world, they must have huge networks of technical servicing.

Professor Simon Blackmore: They do.

Lord Cameron of Dillington: You would have thought the Massey Fergusons of this world, the biggest tractor builder, I think, would be moving straight into this field.

Professor Simon Blackmore: All the big tractor manufacturers know all this—I am in discussion with them and we talk about these things—but it is too disruptive for them. They will wait until a start-up company comes and produces these things and then they will probably buy them after they have started to be successful.

The Chairman: Professor Blackmore, you mentioned the benefit of technology bleed-through from roads to non-road use. Is this something that Innovate UK or other government departments are encouraging and championing?

Professor Simon Blackmore: We have a community where we share, but I think there are more things we could do, certainly. Where more money is thrown there is more advancement, usually; the more money that has been put into certain areas the greater the results we have ended up with. I think the agricultural sector could benefit from utilising some of the tools and techniques that have been developed elsewhere, perhaps more than we are at the moment.

Dr Rob Buckingham: You heard from Iain Forbes earlier about CCAV. If you think of connected and autonomous vehicles not as driverless cars but as autonomous vehicles, that could be a way of broadening the impact across many sectors. For instance, if we are thinking about autonomous delivery of food and drugs in hospitals in the future, you should have somebody from the Department of Health who is part of that group who is at least thinking about the implications for this new technology within that sector, and the same in the agricultural, military and transport fields. You could strengthen CCAV to make sure that we have a big impact in the whole “autonomous vehicles on the roads” field, but be aware of the impact into broader government issues. The Government have a number of key roles here: as investor, and obviously as representative for and of the people, but also as a user. The Government will be a major user of these technologies, and we hope that that will be a way of delivering better services and bringing down costs.

Q19 Lord Hunt of Chesterton: We had some discussion about the United States having a long record on autonomous vehicles. Are there programmes in America or investment by DARPA, and so on, in these areas? Once they find their money, there

is so much money it becomes difficult for the UK to remain competitive. I wondered what the situation is.

Dr Rob Buckingham: Yes, they are; yes, they will spend an awful lot of money; yes, we have to respond.

Lord Oxburgh: Who are our major competitors in this area as far as automated agriculture is concerned?

Professor Simon Blackmore: The market itself is very low at the moment because it has not been commercialised.

Lord Oxburgh: Who are your competitors, as people who are developing the technology?

Professor Simon Blackmore: As with most university research areas, we talk to each other around the world. Japan is obviously very advanced, Denmark is very good and the US is very good. Coming back to the previous question, the difference is not necessarily the technologies—because we learn from each other as academics what all the new technologies are and how they work—but a different cultural way of thinking in terms of investment. There are quite a number of agricultural start-ups in California that are now getting \$16 million here and \$15 million there to get these things going. Of course when you put that amount of money into it, it is going to happen; it is just making it happen. We are always scratching around for £100,000 here and £100,000 there and it limits what we can do. They are not any further ahead—in fact, I would suggest they are behind us—in terms of the technology, but if we want to make it happen then we need more investment.

Lord Hunt of Chesterton: In quite a few areas such as nuclear, nuclear waste and fusion, the UK is very strong. I am surprised you did not come up with that, as it were. The United States has been treading water.

Dr Rob Buckingham: Yes, absolutely, in that sector they have, and Fukushima will be the major driver for technologies which are developed for operating in those extreme environments. Within Sellafield, for instance, if we are going to get on top of those costs, we need the toolkit which does that cost-effectively and safely. We should be ensuring we use some of that money to push this technology forward. This is my point about needing a leadership council to make sure we invest in the right areas, because we will not have enough money to compete across the board. Therefore, we need hardnosed decisions on how we use this money for national interest, to meet our current liabilities and our own internal opportunities, and then the export markets, especially with Brexit. What are we going to be absolutely world class at?

The Chairman: Lastly from Lord Maxton.

Lord Maxton: Professor Blackmore, does this make a small-scale farmer less economic, or will it in the long term, and therefore put the advantage back to the big farmer?

Professor Simon Blackmore: No, I believe it is the exact opposite, and I will tell you why.

Lord Maxton: One would hope so, yes.

Professor Simon Blackmore: The big machines are very efficient but they require the big fields. That is why we used to take out the hedgerows, and so on; we modified the environment to suit the machines. Now we are making the machines clever enough to deal with the environment, and making them smaller. If we are looking at this from a global point of view and where we are going to get all this extra food from, I do not think it is necessarily going to come from increasing the efficiency of the big farms; they are already very efficient. The extra food production is going to come from the small to medium-sized farms that then do not have to invest £200,000 in a big tractor but invest £20,000 in a robot to do the same job but on a small scale rather than a big scale. I think it will have the opposite effect: it will support the family farms and we will get extra production from smaller farms and fields. I think that is where the extra food is going to come from.

The Chairman: I must bring this evidence session to a conclusion. You have made the very forceful and fair point that hard-nosed decisions on the national interest are going to have to be made. This is an area where, as we take evidence, we are going to have to decide for ourselves and others where we are indeed of world-class status. If you have any further thoughts on how you feel the decisions should be made and which areas to concentrate on, do please send us a note to develop that. I am particularly struck, also, by the implications on infrastructure and telecoms. You are talking about moving from a driver in a cab or in an autonomous vehicle of some kind to somebody controlling it from his or her desk; again, are there infrastructure implications we have not had time to cover on this? If, again, you would like to send a note on that, please feel free to do so.

Professor Blackmore and Dr Buckingham, thank you very much for a most interesting session. We will be sending a transcript of the session, and if there are any inaccuracies in that transcript you will have an opportunity to make corrections. On behalf of the Committee, very many thanks for your help.