



HOUSE OF LORDS

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Inquiry on

DIGITAL SKILLS

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Witnesses: Professor Nick Bostrom, Michael Gleaves and Kevin Baughan

USE OF THE TRANSCRIPT

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Members present

Baroness Morgan of Huyton (Chairman)
 Lord Aberdare
 Earl of Courtown
 Baroness Garden of Frognal
 Lord Giddens
 Lord Haskel
 Lord Janvrin
 Lord Kirkwood of Kirkhope
 Lord Lucas
 Lord Macdonald of Tradeston
 Baroness O’Cathain

Examination of Witnesses

Professor Nick Bostrom, Director, Programme on the Impacts of Future Technology, University of Oxford, **Michael Gleaves**, Head of Business Development, The Hartree Centre, Science and Technology Facilities Council, and **Kevin Baughan**, Director, Technology and Innovation, Innovate UK (formerly known as the Technology Strategy Board)

The Chairman: Good morning. Thank you very much indeed for joining us this morning. You have a list of interests that have been declared by Committee members that should be there in front of you. These were declared orally by members at the previous session on Tuesday 8 July and can be found in the transcript. A couple of members who did not declare interests at that stage because they were not present will do so today. This is a formal evidence-taking session of the Committee and a full note will be taken. This will be put on the public record in printed form and on the parliamentary website. You will be sent a copy of the transcript and you will be able to revise any minor errors. The session is on the record. It is being webcast live and will be subsequently accessible via the parliamentary website. You are also, by the way, welcome to submit supplementary evidence after the session; we would really welcome that. I remind us all—witnesses and members—to speak up so that we can all hear each other.

I will come to each of you to introduce yourselves. If you would like to make any brief opening remarks, you are very welcome to do so, but do not feel that you have to. First of all, Mr Baughan.

Kevin Baughan: I am Kevin Baughan. I am the director of technology and innovation at the Technology Strategy Board and I am happy just to move to the questions.

Michael Gleaves: I am Michael Gleaves. I am head of business development for the Hartree Centre, which is a supercomputing centre based in the north-west of England. We look at supercomputing, big data analytics and visualisation, and try to apply that to industrially relevant problems.

Professor Bostrom: I am Nick Bostrom. I am the director of the Programme on the Impacts of Future Technology and of the Future of Humanity Institute at Oxford University.

Q26 The Chairman: Thank you very much indeed. Let us kick straight off into the questions and first of all a broad one for all of you.

Can you help describe for us the pace and change of the future digital landscape over the next five, 10, 15 years and in broad terms outline how you think that is going to affect our society, our workforce, our economy? So no challenge there, but if you can just help us paint that picture to start off, it would be really helpful.

Kevin Baughan: With pleasure. In my group we have huge involvement across multiple sectors in the UK economy. As a consequence we can see digital penetrating each one of those sectors. One of the key characteristics that is changing is really the fact that digital is embedding itself into almost every sector we work with. Whether it is agriculture, transport or manufacturing, all of those now have a digital dimension. So we structure our own activities very much with a digital team that works alongside each of the sectors as well as on digital-specific areas. I think that is probably one of the biggest changes. That means that we see a world now that is moving beyond fascination with accessing the digital world and connectivity to one that goes right inside it to understand how data can transform entire industries—how the analytics of that are becoming increasingly important, how really it is involved in design, in simulation, in testing—because if you can move into a digital dimension the costs of an industry are completely different; you can experiment, you can change, you can understand and therefore the world is one where you can be much more productive. So it penetrates all those different aspects.

Then if we look a little bit further out we can also see the fact that the digital world is changing the form of production as it moves into 3D production and even into robotics and autonomous systems; the virtual world is becoming more physical again. Those kinds of technologies are allowing the equipment to perceive, to reason, to change their purpose and therefore we see a further transformation. So that digital world is infusing itself in almost every aspect of each sector.

Michael Gleaves: I commend what Kevin says, but I think that one of the drivers is Moore's law. Are you familiar with the law that every 18 months your computer gets twice as fast? That means that the fastest supercomputer in the world 20 years ago is now the same computational power as an iPad today. Put another way, a room full of computing is now an iPad that you can carry around with you. It is just a revolutionary process. If I take that forward again, if I run it on my fastest supercomputer in my computer hall a calculation for 10 minutes, that same calculation would take 16 years to calculate on that same iPad. So basically half a lifetime's research can be done in 10 minutes on the fastest systems in the UK today. That Moore's law generates the availability of computing but also the cost. So the cost of computing per core hour is plummeting over time down to couples of pence per core hour right now. That is driven right now by the rise of parallelism. Everybody remembers that they had a single core and their computer got faster every time they bought a new one. Then Intel produced Core Duo and nothing got faster but you could run two applications simultaneously. Now you can run four, eight applications but the code is not getting faster, unless you write it, to be able to use that parallel system. Computers are also becoming more heterogeneous, so there are accelerators in those systems, whether they are

graphical-processor units or other accelerators, and they are even more complicated to code and use. So the problem of how to use the computers that are available has been moved from hardware company to the software developer, and that is where we need to invest the skills to use these technologies that are ably being created by the hardware manufacturers of the globe.

The other thing is data: the rise of data right now is huge. From 2006 you can see huge uptakes in the amount of stored data and particularly data that are IP accessible, so they are in a form that you can connect to over the internet and you can analyse them in real time to give insight and actions that can make significant differences to business's operational costs but also innovation.

Professor Bostrom: I want to fill in a little, more briefly perhaps. One might disentangle two kinds of trends. On the one hand we have a continuation of the types of developments that we have seen in the previous five, 10 years—specific new innovations but of the same kind and the same magnitude where the internet remains an extremely exciting frontier of entrepreneurship—and new applications in governance and business: in all sectors really. Education is another thing that is up for being revolutionised. That, it seems, is fairly predictable, not in the specifics but there will be more.

The Chairman: It is a general direction.

Professor Bostrom: With the other thing I think there is a lot more certainty, and this is the rate at which we will see advances in machine intelligence. At some point, partly due to the increased computing power available but also through progress in algorithms and in cognitive science perhaps, computers will become more and more capable not just to crunch numbers but to detect patterns, to do more abstract reasoning and eventually to begin to substitute for human intelligence in a wider range of domains through having general learning algorithms. There is a great deal of uncertainty as to how quickly that will move, but that, I think, will have important implications in the shorter term for how many different jobs can be automated; driverless cars are one application, but there are a lot of different occupations in principle where you can see this too. In the longer term there are even more profound issues: one is considering scenarios where computers eventually match humans in general intelligence.

The Chairman: Can I ask a supplementary? To what extent do you think policymakers understand the big change that is happening now and is going to happen? Are there any lessons from previous periods of fast technological change that they ought to be looking at and applying?

Professor Bostrom: To a very small extent, I think. If one is thinking about several decades out, the most aware just recognise some possibilities to have some thinking. The policymakers' attention by necessity is focused more on the short term, and there is an awareness in the sense that, yes, we recognise for example that information technology is important—presumably that is why you are all here—but you probably know more about the degree to which policymakers at large know the specifics.

The Chairman: We are fairly depressed about it at the moment.

Michael Gleaves: I do think that industrial pull is one of the most important: being able to demonstrate the state of the art in an industrial setting that creates the need but then creates the requirements for the universities to produce the staff. The future generations

with those skillsets that are being pulled into industry is pretty important. Policymakers can build centres of excellence that can be focus points for these types of technologies and can be demonstrators that help to make the business case internally for those businesses to make those investments. Some of these investments are large investments on an industrial scale.

Kevin Baughan: We see a good relationship-building across multiple government departments in this kind of area. We obviously work a lot with BIS and other government departments, and we find them very supportive of the Technology Strategy Board in our work. If you look at our delivery plan, in each of the areas you will see sectors that are being transformed and encouraged to take on new technologies, and there is quite often a very strong digital element in particular in that. If you went to the construction industry you would find discussion around building-information management systems. None of the sectors is changed and we find a really good resonance there, but the scale and pace of change is always one to underestimate. You asked if there were lessons to be learnt. I think one is not to be scared of these changes, to embrace them, to get on top of them. I have lived long enough to see a few scare stories about what technology can do, but if you can embrace them and use them successfully they become very powerful forces not just for the economy but for people's lives and for the quality of the experience.

The Chairman: Thank you.

Q27 Baroness O'Cathain: This is amazing stuff, but thinking about the business sector, who is going to be the champion of this great progress? Looking at board structures, you have a director of finance, a director of personnel, a director of something else. Where is digital going to sit? Do you think there is a case now to make sure that the FTSE 100 companies in particular realise the impact that there is likely to be and that they ought to have a digital champion on the board as a director of digital? What happened in this country just about 20 years ago was that engineering directors went off boards and engineering became plumbing. This is too important, not just to the UK but looking at where the competition is coming from. You say that the Government are taking this on board. What about major manufacturing, retail, education, all sorts of companies? Do they have a digital champion—somebody who really is the one to direct the digital programme in that company—on the board? Otherwise it is not going to run.

Kevin Baughan: The point you raise is extremely important. I think that the people who lead the products, not just the technology departments, are going to be at the centre of this, because they need to understand that their entire product portfolio and their whole approach are changing. So I do not think it is going to become something that will be put in one corner. I really hope that it is not. I hope it becomes absolutely central to the lead member on the board for the product as well as for the technology. Clearly the finance departments are involved in all those discussions. In fact, if you look at industry, the one that I get most nervous about is the small to medium-sized enterprise industries. I think the big corporates are powered to change because of the competitive worlds they live in. The smaller micro-industries tend to change dynamically because they need the benefits of digital for their businesses. The small and medium-sized enterprises—the ones that are busy just meeting the payroll and doing their activities—are the hardest ones to change, the ones that I think probably need the most help.

Baroness O'Cathain: They think they can buy it off the shelf but they cannot.

Kevin Baughan: Yes.

Michael Gleaves: There are some great examples. I do quite a lot of work with Unilever and they have a senior vice-president for R&D who is very into digital and simulation. They have set up focus groups, internal groups, to look at these technologies, which is quite productive, but that is probably a highlight.

The Chairman: Anything to add or we will move on?

Professor Bostrom: Outside the business sector there are big opportunities in governance and education that you should also bear in mind.

Q28 Lord Haskel: Thank you for that tour d’horizon. Very interesting. But I wonder whether we could come down to the more particular. Could you tell us which technology trends will have the highest impact for us here in the UK and how these technological developments are going to be different from the ones in the past?

Michael Gleaves: We have just embarked on some work on energy-efficient computing, and one of the routes forward on that is the ARM processor, which is obviously a Cambridge company. They have their 64-bit extremely energy efficient computing, high computing power technology systems. One of the real opportunities for the UK is to combine technology and design. The really successful organisations within the UK—the Dysons, Bentleys and Jaguar Land Rovers of this world—are not just technically brilliant or engineeringly brilliant; there is also a high level of design and design ethics in the product, which makes them better because they are British to some extent. There is also R&D and the likes of the really R&D-intensive industries such as the aeronautical industry and the pharmaceutical industry; and the application of data analytics, computing simulation, and using data analytics to get to the right market segments can be a very powerful way of organising your business.

Professor Bostrom: I do not know whether you would count it as a specific technology, but there is a particular type of application for it in general transparency or surveillance, depending on how you look at it. More and more data are becoming available off what people are doing—their behaviour—and what things are doing; more and more things will have embedded chips that can communicate with other chips. I think we are moving into a social domain where there will just be a lot more data available that can be processed and mind patterns extracted. It can be used to target advertising and police populations, to customise experiences to the individual user’s preferences, and for other things that we have not dreamt of yet that can be built on top of this mountain of data. There will certainly be business opportunities in that direction, but there will also be challenges in how you trade off privacy concerns while giving people opportunities to put different datasets together to find these new opportunities.

The Chairman: Mr Baughan, do you want to come in?

Kevin Baughan: Just briefly. I think I will frustrate you a little because I do think it is very, very pervasive. At the end of the day we live in an innovation economy, so we succeed by innovating, and in the Technology Strategy Board we are very focused on that as a means of accelerating growth. But whether it is the creative industries that now have 80% of their films in a virtual world instead of a physical world, whether it is transportation and bringing together streams of information for more intelligent mobility, I struggle to find any one of them [that is not involved in this]. Some are more established, particularly high-value

manufacturing and leading companies in that space, be it Airbus, be it Jaguar Land Rover. Those are very far advanced in this, but I think it will pervade everything, and that is the challenge that sits before us.

Lord Haskel: While all this is going on—we hear what you say—the economists tell us that productivity has not moved in the last 10 years. There are more people at work but we are still not producing more. What is happening with all this? Are we missing out by people not learning the skills? Is that what we are missing? That is what this Committee is about.

Kevin Baughan: Perhaps we could move into the skills area. Obviously we approach it from the direction of business and what is happening in business. The first bit of good news for me is that the United Kingdom is a nation that has embraced going online. We have very high penetrations of that. If you look at the technology trends, they are moving towards much lower costs and making it much easier to use, so at the end of the day I am less concerned about people becoming familiar with technology as users because all the trends are in the right direction in the sense that we already embrace it. The cost of accessing it is coming down, the ease of using it is going up, and that is an encouraging environment.

Where I think the real work lies is in making sure that we can fuse worlds together so that there is a digital dimension to the way you study subjects as you progress through your education and you can enjoy the benefits of that, be enriched by that and get inspired by that and want to participate. It does not take away the need for expertise; it just needs to be combined with tools and knowledge as to how to play with your expertise in a digital domain before you do something in the physical world.

Professor Bostrom: With regard to productivity, I think there is also an issue of econometrics there in that some of the benefits created by the new digital world are not included in GDP; a lot of services online are free. I use Google search engines and all kinds of products that enhance my life a great deal, but I do not pay for them so they are not included in the accounting. So to some extent it is an open question as to how much productivity would have grown if we had fully accounted for these kinds of benefits.

The Chairman: That is interesting.

Q29 Lord Lucas: I will first declare my interests. I am in the process of founding a social enterprise in the career space, which will be very heavily reliant on a lot of digital technologies.

Professor, if I can pick you up on something you said about the use of our personal data, do you think that we as politicians should be thinking about developing a personal information right so that individuals get back some control on the way that companies and Governments are using information about them?

Professor Bostrom: I am not sure what the correct solution is either way. I have not made up my mind. I think that some choice will have to be made. My guess is that it will de facto go towards transparency and data becoming available, because there is something that is known as the promiscuity of data, which is basically that a given set of data, even though it looks like it is only about a certain thing, once you combine it with other datasets, turns out to have implications for all kinds of things that were not explicitly included in either. So it is quite difficult to lay down barriers between datasets that will really last. You can try to anonymise data, for example, but often if you are a clever person you can find ways to de-

anonymise the data; if you put enough pieces together you can identify whose data they were.

So in the long run my guess is that we will move towards this more transparent route where certainly the Government and security agencies can see everything that everybody is doing. But one question is whether it will also be possible for corporations to see what everybody is doing and for networks of citizens to create their own surveillance structures and so have access to the same data; whether it is a one-way transparency or a two-way transparency. So I do not have any opinion one way or the other on this specific initiative. Maybe it is a good idea, maybe it is not. It is hard to imagine politicians making this choice once and for all. I think it will be an evolving social dialogue with adjustments along the path.

Q30 Lord Janvrin: We have begun to touch on this. I would like to hear from each of you what you think the main challenges are likely to be as the UK attempts the transition to this kind of knowledge-based economy. We have had a bit about the opportunities, particularly on the business side. Are the challenges skills-based, educational or regional policy? All of the above, no doubt, and many more, but I would be very interested in what you see as the major challenges that we are now facing.

Kevin Baughan: Probably they come in two big groups, one of which is encouraging people to have the confidence to invest. In the UK we are not that good at investing from both the private and the public sector, and if you are facing large transformations you really need people to be comfortable about investing and confident in doing so. We could talk further about that.

The other aspect is the skills dimension. I look at it as a challenge of fusion—fusing things together—because at the end of the day if digital just becomes the next phase of ICT programme, it stays in an engineering domain and stays thought of as the preserve of people who like engineering. It is not. At the end of the day I would really like to see it be the fusion of creativity, expertise and commerce. With creativity, it does not really matter whether it is art or design. With expertise, it does not really matter if it is construction or sciences. With the commercial bit, it does not really matter if it is psychology and understanding people or business studies and understanding finances. It is that fusion of subjects and encouraging people to really bring them together that I think is the most exciting piece going forward. If we can find ways to encourage people to do that, I would be much more confident.

Michael Gleaves: Yes, I would say that STEM graduates are really important in this process, but they must be taught how to think in a simulated or data-analytical way as well as the chemistry-domain knowledge that they have. It is only when you get both those components together that you get the real insights. There is a book by Jim Gray called *The Fourth Paradigm*, which talks about the four different paradigms, starting with analysis, experimental theory and simulation. I notice that Dominic Tildesley is now the chair of the Royal Society, and he is a modeller and simulator, so that is now establishment, so the only one left is really the data-driven science that he was pushing on. That is the level that domain skills and expertise need to be embedded in the chemists, physicists, engineers, marketeers and business-development managers of the future.

The Chairman: Would you say that is not the case at the moment?

Michael Gleaves: Not at all. We run summer schools to try to teach graduates and postgraduates, typically from the PhD levels up. So this year we are running whole-week

summer schools in high-performance computing, visualisation and big-data analytics for cohorts of 50. But it is only 50. It needs to be pervasive.

Lord Janvrin: You could do a summer school for Peers.

The Chairman: We would take longer, I think. We would need a couple of years.

Michael Gleaves: We will take up that challenge if you wish.

Professor Bostrom: One challenge is the comfort level that different people have with digital technology. I think there is a generational gap there. Generally speaking, younger people who have grown up with it take a lot more things for granted and are happier to access government services, banking and financial services and other things through the internet. From an economy point of view, creating the culture of entrepreneurship like one sees in the Bay area, where it is normal to start up a company and have it fail and then maybe start again or join somebody else's, is a very different outlook from the traditional model where you joined a corporation when you were 20 and then maybe expected to stay there for the rest of your life. If you then lost that job, it is a big failure, whereas in the modern economy it is important to expect that you might change jobs frequently. I think the impact of unemployment is not just about losing money or a livelihood; it is also feeling like a failure. If there is an expectation that you are supposed to hold on to a job for ever and you then do not, it is a much bigger psychological blow, so creating that kind of expectation that one will need to be flexible to thrive in the new economy is important.

The Bay area also suggests another challenge, which is that it is above anything else a geographic cluster, and we see it in other sectors as well. There are biotech clusters of excellence where you have a critical mass of components coming together: cutting-edge researchers, people with money, people with experience running start-up companies, designers, other kinds of support services. That suggests that in the UK there might be one or two clusters that will be hot beds of innovation but other parts of the county are left behind.

It is not obvious how best to respond to that, because these clusters form because they create network effects, so by trying to spread everything out you might put out the fires, and perhaps counterintuitively one should try to encourage this kind of concentration to reach critical mass where you could get something that is meaningful at a global level.

Lord Janvrin: Can I just come back to Kevin Baughan and your very first point on the confidence to invest? You said that more could be said about this. Could you say a bit more about that against the background of what we were talking about—top senior people in business are not as digitally aware as they should be—and against a background of well documented failures, particularly in government projects, which is an inhibitor to thinking creatively about investment? Could you say something on that very good point you made?

Kevin Baughan: Yes, certainly. I think we can approach it from a couple of angles. Obviously one of the Technology Strategy Board's roles is to encourage innovation and accelerate economic growth by looking at the barriers to various aspects, so at the end of the day when we look at sectors we work with the industry to understand the barriers that are preventing them from going forward. Sometimes they could be regulatory barriers, other times they could be ones that are based on the perception of the level of risk that they have to undertake. Therefore we can get involved to look at finding ways to go through those barriers and see when it makes sense to use public money to do it and at the same time

encourage them to develop skills so that they can tackle those things themselves with private investment. Some of the more interesting aspects of the work that we do is where we have projects and programmes such as the catalysts, which then stimulate activity in a sector but measure their success by looking at the ongoing private investment that follows the public investment that was made to trigger the change in the industry. Whether that is in agri-tech or in biomedical areas, it is a way of helping the industry gain confidence and direction.

But that is only part of the challenge. The other half is having UK industry prepared to invest at a higher level than it is at the moment, which I know the Tera Allas report and others from BIS have looked at in detail. There is a role that we can play in public funding to trigger people, give them confidence and build a consensus, and some of that is as simple as stretching out the road map—the strategy for the sector—with them so that they can understand the direction they are going in. Then if there are specific barriers, we can try to overcome them or stimulate the opportunity. But I think the country as a whole has to get better at managing and feeling more comfortable with risk, because that is what we are in when we are investing in transformation.

Q31 Lord Macdonald of Tradeston: I declare an interest in digital skills and competition as an adviser to Macquarie Infrastructure and Real Assets and as a non-executive director of Scottish Power.

We heard previously about the large adjustment shock that there might be as workers are laid off and that the wages of unskilled people might fall below socially acceptable minimums, which, combined with new technologies, robots and so on, might make the distribution of income even more unequal. This really goes back to the question of the challenges that we face if we are to remain a leading innovator in this area but also have to adapt to cope with the social consequences.

There is an election next year. What would you suggest people put in their manifestos?

The Chairman: Excellent.

Kevin Baughan: I will leave each party to decide what they put in their manifesto, but the thing that interests me is not to be scared to use the power of digital to tackle some of those problems. At the end of the day it is a great leveller. It creates opportunities to perform at a global level from a very small base. Those opportunities do not necessarily suit everybody; I fully accept that. But there are some enormous opportunities that stem from the technology itself as well as some change in the way people live their lives and the way they work. Clearly we have to be focused on addressing those who are excluded for whatever reason and finding ways to support them through that, but the younger generations are embracing this at pace, so it is really trying to take that enthusiasm, understand how it might lead to more entrepreneurial activity, and understand how it might lead to more opportunity inside industries. For me, we can scale up tremendously here in the UK. We have a lot of leading-edge technologies, and I do not think we need to be nervous at all about the outcome if we embrace it. I have a lot of confidence that it will create a lot of opportunities as we come out of it if we embrace it. The difficulty is that if we hold back, others will seize the opportunities and take economic activity away from us.

The Chairman: I am going to give you a warning that at the end of our session I am going to ask you for one specific policy recommendation that you would give to us as a Committee.

We are going to try to nail you down a bit more, Mr Baughan, than you have just done: to move from the generic to give us one thing. What would be your top choice? I will come to you right at the end, but first Mr Gleaves on this question.

Michael Gleaves: This is a very fast-moving area and there is an element of continued professional development. It is learning for life, and it needs to be embedded within the culture of our nation that people need continually to re-educate themselves and build new skills. Big data were not even heard of five years ago and now they are being used effectively with lots of businesses. There is a requirement for the people within those businesses with all those domain skills to go back out, re-educate themselves and then reapply that, and that may drive some of the efficiencies within our Government.

Professor Bostrom: On the inequality thing, I do not have a panacea, but I would just note that if there are increasing effects from one type of development, there are these traditional methods of progressive taxation or whatever where you can tune a parameter up or down to combat inequality. So if one is concerned about inequality, an inefficient way to deal with that might be by trying to reduce the pace of digital innovation and it might just be better to make the taxation system more progressive.

An answer that will often be given is that education is the key; everybody has to have a good education. I think there is truth to that, but it is also not necessarily easy just extending the period of education; it might be that we are at the point of diminishing returns where we have a sort of certification arms race. It is not so much that you need to have the MA to be able to do the job; it is just being able to get the job. You have many applicants. One has the MA and one does not. The MA guy will be hired but it might not add so much value to the economy as a whole. So improving the quality of education perhaps rather than the quantity would be another suggestion.

The Chairman: Lady Garden, do you want to come in, because your question carries on really.

Q32 Baroness Garden of Frognal: Yes. You have all already spoken about skills, but I wonder if I could ask you specifically what hard and soft skills need to be developed within the talent pipeline to ensure that our future workforce is adequately equipped and are these skills transferable across occupations and industries. I think, Mr Baughan, that you have already suggested that they are embedded across industries and occupations, but how do we ensure that the people who are coming into the workforce have the right sort of soft skills as well as hard skills?

Kevin Baughan: The challenge is that everything moves so quickly in this digital space. If you try to design courses and roll them out, by the time you have finished them the world has moved on. So some of the more important aspects of learning going forward are really self-learning and peer learning. That is another aspect where clusters are so important: people learn from each other; they pick up on each other. Again the technology direction is such that people do not write user manuals any more in the expectation that they will be read; it has to be intuitive. People have to learn to pick things up. So I think the kind of areas that are important are the ability to learn yourself, the ability to learn from your peers, and the ability to keep that going informally as well as formally. There is still a very important need for formal education. All this depends on good science, good engineering and good art,

whatever the foundation. That does not disappear. But the ability to apply it has to be done at speed, and there are different skills in that.

Just to pick up on Professor Bostrom's point as well, people on the softer side need to be more imaginative, more innovative and more entrepreneurial if they are also going to flourish in a fast-moving world, because they have to be on the front line of that. On the softer side it is those innovation skills and leadership skills for change, whether at the board level or further down, that are important. I have those two things in my mind, which are, I think, very transferable at the end of the day, because they are really life skills in a fast-moving world.

Michael Gleaves: There are a couple of points there. First, the managers and directors within institutions need to be able to communicate with data analytics people and computing people in a way that sets a question they can answer. So there is an upskilling of the management layers of businesses in how to communicate to these groups and how to get the best out of the activities that they do. I have mentioned this a number of times: it is down to domain skills. These skills need to be embedded in the scientists, the engineers, the physicists and the astronomers, and it is when you get that embedding that you really get the upskill and the uplift in people's ability to give you an answer, an insight and an action, and it is the action that is important, not the insight.

The Chairman: Thank you.

Professor Bostrom: One can point to specific technical skillsets that would be useful. The data scientist role seems to be one where there is increasing need for somebody who has the technical chops to dig through big datasets and do statistics on them but also the business acumen to try to figure out something useful for the business that would affect the bottom line and the ability to communicate that. It is a hybrid of the traditional nerd type but also somebody who can spot opportunities in the economy. In a wider sense, of course, the future economy will need a very wide range of skills. Most people will not be doing technical work with computers. A big chunk of the economy will be taking care of other people in some fashion—in the healthcare system, with the elderly, in tourism and in service industries—so very different kinds of qualifications will be needed.

Perhaps the most important thing, though, is to inculcate the mindset that skills are not something that are foisted upon you in school, you are a passive recipient and then you continue on for the rest of your life with the skills you were given, but rather that if there is some skill that you need and that you have the confidence to try to learn, either just by browsing the right website—there is so much beautiful material now: instruction videos, online courses, infinite opportunities really for somebody who has the time and inclination to learn themselves—or by joining some continuing education course and having that sense that you can and that it is up to you, is probably more important than any particular skill.

The Chairman: That is really interesting. Thank you.

Baroness Garden of Frognal: Is there a call for some changes in teaching methodologies in schools, which obviously are adapting all the time anyway? You are talking a lot about self-learning and not following manuals but learning from peers, and there are lessons there, are there not, for our school education system presumably, too?

Michael Gleaves: I have a seven year-old, so I bought a Raspberry Pi and I tried to get her to do a bit of hacking—it takes a while—but that is not what they are teaching them in the primary schools, unfortunately.

The Chairman: No. We have already had evidence from somebody who said that the best thing that we could do would be to make sure that every child had a Raspberry Pi, and that would move them on.

Michael Gleaves: They are great little devices.

The Chairman: Thank you very much.

Q33 Lord Giddens: I wonder whether I could ask Professor Bostrom to quickly say a bit about his book *Superintelligence*, because I think it might interest the Committee. It seems to me we are at the outer edge of this amazing global surge of change, and we just do not know what the reality is going to be. You probably do not want to talk about the simulation argument.

Professor Bostrom: If one is taking a wider perspective and looking at that longer term, at the moment, and for all of human history, the human brain has been where it has been at regarding information processing. It is the only general intelligence system that we have had, which is why humans have created these complex civilisations and why it is us rather than the gorillas who are running the show. It is because our brains are slightly different from those of our ape ancestors. At some point, I believe that machines will surpass us in general intelligence and then, for precisely the same reasons that we are now powerful compared with other animals, machines will be very powerful at a later time.

Lord Giddens: You think the point of singularity might be quite a long way off from the one like Ray Kurzweil's?

Professor Bostrom: Nobody knows with any precision how far off these kinds of developments are. Therefore, rather than picking an arbitrary date or dismissing it, one should think in terms of probability distribution smeared out over a wide range of possible arrival dates. It seems that there is a fair probability that it can happen by mid-century or at least before the end of this century, but it could happen much sooner or later. The consequences would be momentous. It would be the most important thing that has ever happened in human history, with enormous dangers, and it would be key to try to set up the initial conditions so as to make such an intelligence explosion survivable. But for more details on that I would urge everybody to buy a copy.

The Chairman: Summer reading, yes.

Lord Giddens: We are not going to buy it, we are going to get it free online, are we not?

Baroness O'Cathain: We are now building up a booklist.

The Chairman: We are. We are going to have a summer reading list.

Baroness O'Cathain: Can we make a note? *The Fourth Paradigm* and then this book by you, so please note.

Q34 Lord Giddens: There is also this famous computer simulation argument that we might all be in a computer game and you can demonstrate this mathematically. Anyway, I do not want to waste the Committee's time.

I feel that all these general issues are very relevant to the immediate on-the-ground ones—the reason why I asked it—but I would like to push you a bit on what you would say about the impact of supercomputers and robotics on the labour force and the processes of deskilling as well as upskilling, because Dr Frey and our Committee have written extensively about these and it seems to me that it is another wave of change and it is hard to grasp what the significances and consequences will be. Will supercomputers knock out a whole range of jobs in the labour force?

Professor Bostrom: Yes, there will certainly continue to be turn in the economy, new jobs created and old jobs disappearing, perhaps faster than the usual rate. To me the main reason why this big picture thinking is relevant for present day concerns is that it is not always obvious otherwise what the right direction is that we should be headed in. If one is concerned about the very long-term outcomes for humanity, it is not at all clear to me that we would want faster progress in computing technology, for example. I think that hastens the day when we will have superintelligence and maybe we would be better off with more time to prepare for that, but that is a bigger discussion.

But if one is just looking at the local benefits to people right now and for the next decades, it seems faster progress is good because it boosts the economy in the short term.

The Chairman: Thank you. Does anybody else want to come in on that?

Kevin Baughan: We have done a lot of work in robotics and autonomous systems, and a strategy has recently been published from the organisation. There are several dimensions to that, one of which is about pushing our boundaries, being able to go into places that are more dangerous, more dirty and more difficult than we would normally be able to as humans, and that is the inevitable direction that humankind has always taken in finding tools and vehicles to do those kind of things.

You could take another example and say, “What about driverless cars?”, but is it yet within the comfort range of most of us around the table to get into a car in a driverless environment? We are probably a little bit away from that. At the moment we are quite happy to get into a pod at terminal 5 and find ourselves delivered from the car park to the airport. Fully autonomous systems will take some steps to get there. But at the end of the day is it about transport in the city becoming so congested that you need different types of solutions in order to make it work? If you did not have to drive a car, are you now more productive with additional leisure time and work time that you could have used when you were behind a wheel trying to negotiate your way through a difficult piece of congested area?

Every time the autonomy or the robotics brings in a change, at the same time it frees you up to do something else. If we are constructive about that transition, suddenly the productivity rises, or your own personal enjoyment rises, because in the time you would have spent driving your car you are now able to relax and enjoy it, and when you get to the destination, just as you would in a coach or an aeroplane, you are just grateful to have had that extra time to be able to get there.

It is definitely one that you have to think through, and quite often the benefits come through stronger than we were expecting. Quite rightly, the first step is to be concerned about the change, but then quite often the benefits flow through more strongly than everyone was expecting.

Michael Gleaves: I would just like to make a point. I was lucky enough to go round a Mercedes engine plant in Stuttgart six months ago, and that site has 120,000 working people on it but only five on each line with 12,000 engines, who are making the engines. So I asked the guide, “What has happened to the people who made the engines?”. They have been redistributed through the business into marketing, design, engineering, so the same number of people were working on that site but they just were not doing the manual construction any more.

The Chairman: They had planned it properly.

Michael Gleaves: They planned it properly. They had moved those people into the tourism, marketing, sales and design aspects of the Mercedes, so businesses can manage that difference if they maintain that high-value product.

The Chairman: Thank you, that is helpful. Lord Kirkwood.

Q35 Lord Kirkwood of Kirkhope: I am interested in inclusion and inequality, but I have a couple of quick questions first to Michael Gleaves. I am finding it harder and harder to sound fashionable at dinner parties these days. Can you explain to me what a petascale supercomputer is?

Michael Gleaves: Yes, I can.

Lord Kirkwood of Kirkhope: In six sentences.

Michael Gleaves: You flip a zero and a one and that is a byte, effectively. A petascale computer can do 10^{15} of those a second. That is it.

Lord Kirkwood of Kirkhope: I am really glad I asked that question.

The Chairman: You can read that answer in the transcript.

Lord Kirkwood of Kirkhope: I know. That is not a dinner party-type answer.

The Chairman: He goes to unusual dinner parties, clearly.

Michael Gleaves: The dinner party answer is it takes 10 minutes to run on a petascale system and 16 years to run it on your iPad. That is the dinner party conversation.

Lord Kirkwood of Kirkhope: That is what I was after, thank you.

Another question, Mr Gleaves—possibly the hardest of the morning. Why are you in Warrington?

The Chairman: There are all sorts of things in Warrington. I object to that.

Lord Kirkwood of Kirkhope: There is a reason for this.

Michael Gleaves: I am part of the Science and Technology Facilities Council, and I am based at Sci-Tech, Daresbury. A synchrotron used to be based there, and the first supercomputers arrived at the Daresbury Laboratory in 1957. They bought two: one as a control system, one as a data acquisition system. We have had supercomputers at that site ever since. The large facilities for Science and Technology Facilities Council are now mostly hosted at the

Rutherford Appleton site, but at the Daresbury site we do compact LINAC design as well as supercomputing modelling simulation and virtual engineering, and a small cluster of businesses are formed around that. A cluster of 140 SMEs are on the campus, which are associated with the work that is done as part of the STFC science programme.

Q36 Lord Kirkwood of Kirkhope: That is a very good answer, and I am glad I asked that. Martin Wolf gave us some powerful evidence and referred to what Paul Krugman had done, which suggested that the clustering overwhelmed some of the aspects of industry itself because of competition for skills and all the rest of it. Should we worry as policymakers about these fantastically highly spec clusters of skilled people around physical facilities such as supercomputers and the inequality that that almost inevitably brings?

I was very interested in your Mercedes answer just a moment ago, because that may be part of the solution. But how is this going to affect Easterhouse in Glasgow? The communities are struggling to do anything. The evidence I heard earlier that glancingly discussed this is that you cannot stop the science, and you would not want to. I think Professor Bostrom was saying that we had to deal with it through redistributed tax and benefit policies. Maybe that is the answer.

This is going to have a massive impact. If everything that can go right does go right, you get your wishes and you predict the future accurately, inclusion and inequality are going to be a huge issue for policymakers. Maybe you will say that it is not your job. What should we be thinking about now to try to address it?

Michael Gleaves: Clustering is definitely a positive effect. If you look at the 120 or 140 SMEs that we have around the Daresbury site at campus that I understand quite well, some of these guys just rock up with an idea. They have no intellectual property, they have no funding, but by putting them in the community where everybody is trying to innovate in the same way, they have accountants, lawyers, infrastructure and ecosystem around them, access to TSB funding, help with that process, and access to EU funding. We have only lost three of these companies. Well, we lost seven but three of them have re-emerged, have phoenixed, so they have been combined with a different company to have a different product and service. Those are incredible figures, and that is the clustering effect. To wipe out those clustering effects just because you want to smear it across the entire country seems wrong to me. It does not seem logical.

Then you are looking at what the policy instruments are to help the areas that do not have those clusters around them.

Lord Kirkwood of Kirkhope: But you would say that we would be right to do that right now: let you get on with what you are doing because that is what you know.

Michael Gleaves: So you encourage clusters and then you think about how do you drive up the level of opportunity in the other areas.

Lord Kirkwood of Kirkhope: But these two halves are equally important to try to get a sensible connection.

Michael Gleaves: Yes.

The Chairman: That is helpful. Does anybody else want to come in?

Kevin Baughan: Just briefly, to show that clustering can happen in every sector. If we look at digital being diffused through all kinds of different industries, we see that we get clusters appearing all over the country as a result of different sectors doing different areas. We have different forms ourselves to try to stimulate some of those effects. We have the catapults and the big innovation centres, which are a cluster in a building in the sense of bringing academics and industrial and facilities together all in one place, but we also have much smaller ones, such as information knowledge centres: we have one out in Belfast in Northern Ireland on security. That is flourishing. A whole lot of small industries have appeared on that domain or go to medical technology up in Leeds, and you have another set of industries appearing around that, so I think clusters will occur in every subject.

Lord Kirkwood of Kirkhope: That is a very helpful answer, but answer me this. Are these clusters self-forming or can government say, “Easterhouse is in a bad way in Glasgow. We want a cluster there for whatever”, and stimulate it? Can they say, “We want to go to a community that is disadvantaged. We want a cluster in whatever”?

The Chairman: Does there need to be a university connection as well, because in previous evidence in previous sessions we had that very strongly?

Kevin Baughan: We can only draw on our experience, which is we apply these things from a national basis. We do not look to drive them from the local side up, but that is not to say that somebody who is more experienced in a local community with local knowledge can understand what could be done there. Our approach is top down. We are coming at it from looking at the national interest, and then the competitions yield where the best location is. So we follow the opportunities. That is not to say that somebody with local knowledge could not understand what a useful cluster could be, but it would have a different shape to the ones that we create.

The Chairman: Lady O’Cathain, do you want to come in, since your question carries on from this, does it not?

Q37 Baroness O’Cathain: It does, indeed. How can girls be inspired and encouraged to choose STEM and pursue careers in the technology industry at an earlier age? I have my own views, but we are here to ask you.

Kevin Baughan: I am happy to start. I would like them just to believe that it is an integral part of what they are studying. If they are studying art and they are designing on an iPad, they are in a digital domain and digital world and can be just as creative as if they were sculpting and with brushes and paint and the rest. If they are studying biology, they could use it to see simulations of what is going on inside the human body and how biology works; they are inside a digital domain. So I would like to see digital becoming so infused that it is not seen as an engineering subject or any other barrier that might put girls off studying it but as just a tool that all of us can use to enjoy whatever we are pursuing, and make it more creative and more invasive in the different areas that people want to be in.

Baroness O’Cathain: The trouble then is the teachers.

Kevin Baughan: But the teachers could have fantastic resources, and this again is when you can use the power of digital. The big supercomputer centre could be a huge enabler. While there might be a cluster of expertise around it, the benefits from it are in the Cloud and available to everybody, so people could come in from any school, reach in and see a

simulation that was running on a supercomputer wherever they are in the country. We have to learn to use the power of digital to also take the benefits back out to everybody.

Baroness O'Cathain: That is what I hoped I would hear. It is a bit like the Raspberry Pi, is it not?

Kevin Baughan: It is.

Baroness O'Cathain: We have to hold on to that and make sure that everybody has the right—of course the computers have to be produced.

Kevin Baughan: If a teacher is running through a simulation of their subject area, it is not so daunting for them to enter an ICT world because it is just showing in a more powerful way what they would have done on a textbook or on a blackboard.

Baroness O'Cathain: It would make it much more stimulating.

Kevin Baughan: Yes.

Baroness O'Cathain: Thank you.

Q38 Lord Aberdare: Can we think a little about infrastructure and what the UK's infrastructure needs are to support a more digital technology-based economy? We have thought very much in terms of hard infrastructure like broadband, wi-fi and so forth, but what elements of infrastructure are needed for the availability of information, for example—I know libraries have concerns about that—or coding skills? Thinking about both hard and soft infrastructure, what could we do to improve that?

Michael Gleaves: We have benefited from the infrastructure funding from the E-infrastructure Leadership Council; I am sure they have presented at this Committee. David Willetts and Dominic Tildesley led an e-infrastructure leadership committee, which was a road map for 10 to 15 years on computing, modelling simulation and the application of that to industrial domains.

I think that, yes, there is an investment in hard infrastructure, but there is rarely the investment in the software, the algorithms and the programs that sit on that. If you imagine that they are the platforms for science for which the applied scientist comes and does the research, those investments in software, hardware and then Cloud or the bandwidth are just the delivery mechanism that gets it out to the users without them having to physically be at the centre.

Another aspect that is important in this is visualisation. One of the things that in the short term can make a real difference to an engineer or scientist is returning the revisualisation of the results of their simulation or data-run analysis, and that empowers that scientist to make a better decision. It puts them in the loop rather than removing them from the workflow altogether, and that is a more empowering way of returning these simulations. So investment in software/hardware simulations is important.

Professor Bostrom: I think having strong broadband and moving to 4G can be helpful, not only because of what the immediate utility of these technologies are but also by being among the earliest countries that move in to the new regime. You will also be among the first to start to experiment with it, so you are more likely to develop the companies that take advantage of this: what you can do on 4G, for example, if you are one of the countries that introduced it first. There could be the spill-over effect for innovation.

Harping back to our earlier discussion about clustering effects, I do think it is important to allow the clusters to develop and reach critical mass, but one way in which one could mitigate the geographic impact of that would be to strengthen communications networks, whether it is roads or railways. It has the same effect of making the whole cluster larger, because it is not the number of miles between two points on the map, it is how long the commute time is. More people could participate in a cluster because the communications are better.

Kevin Baughan: Mike and I were talking earlier about an initiative going on at the moment inside the E-infrastructure Leadership Council, which is looking at “Onramps”—the title they have for them.

Lord Aberdare: What?

Kevin Baughan: Onramps, like an onramp to a motorway.

Michael Gleaves: It is a terrible name.

Kevin Baughan: It is a terrible name but it is the one that it goes by. But what is it after? It is trying to find a way to allow industries in a sector to gain access to high-performance computing and the appropriate codes of software that allow them to run on that, and I would also like to see a more vertical integration of data analytics. I think there is a movement afoot that is there as an investment now. Because it is moving up above connectivity, it is into data and the application of those data, finding ways to then allow industry sectors to have a focal point to understand how to get to the computing resources, the data skills and the visualisation skills that they need for their particular area. The three that have come forward that are the strongest at the moment are in the construction industry, in manufacturing and in finance, but creative industries are there as well, as are life sciences with the digital design of medicines. Each sector is starting to come forward to look at how an investment could be in infrastructure in a slightly different form because it is in a digital space. It is more about data, it is more about analytics, it is more about visualisation, it is more about finding access to things than building pipes.

The Chairman: Lord Lucas is going to nail you down a bit now.

Q39 Lord Lucas: What one change would you urge on us as politicians, through government, that we could make effectively? How would we do it, and at what cost, to improve our digital competitiveness?

Michael Gleaves: I wrote three down but I will go with one.

The Chairman: You can give us the three. We do not mind. Give us your top one and then the other two.

Michael Gleaves: The main specific centres of excellence, the main skills such as adding the digital savvy skills to the main expertise, are the key aspect.

The Chairman: How? What is your policy recommendation? You have given us quite an optimistic picture, I think, of some great stuff happening, and our questions back to you are: how do you make that happen more? How do you spread what you are talking about? How do we put it into practice?

Michael Gleaves: I think you look at market sectors. The north-west of England is strong in chemistry and material science in effect. That cluster is there, so it makes sense to place the

main specific application of graphene technologies or new lightweight material technologies in that area. Glasgow has a heavy industrial heritage and perhaps you would look at something in that area to try to build a cluster around that. I think that those act as melting pots and things for things to cluster around to demonstrate that capability.

The Chairman: That is helpful.

Kevin Baughan: I had a very similar comment, which is a kind of one liner: do not make the next phase of digital an evolution of ICT. I think there should be a real break point in that so that we then inspire everyone to get involved. How do we do that in a powerful, cost-effective way? I think that comes back to the observation of using the power of digital to do that. If there is domain expertise in a particular area, do not be frightened to use the power of digital to take that out into every school or every college or every university. Do not confuse the fact that it is centralised for where it happens to be created with the ability to take it back out again. I think the costs are more controlled because you might be doing it once centrally but you then distribute it nationally. If we put those two pieces together we start to get a formula that might work.

Professor Bostrom: I think there will be a massive premium in the digital economy on being able to attract the top global talent to your country, and there should be policies that could help with that. You can imagine that instead of just passively sometimes opening the door to immigrants and sometimes closing it, you could have a headhunting programme where you might advertise in countries where there are few opportunities to try to attract bright, young people without means to come here maybe to study. If they started a company during those years, they might have the opportunity to get to citizenship, so maybe we could embed them during their period here with opportunities for entrepreneurship and put them in contact with networks of mentors and locals. We should seek them out and make an active effort, just as a company would do that tries to recruit the best: they do PR, they look around, they go to job fairs and advertise in all kinds of places. Countries might want to consider doing the same.

The Chairman: That is a controversial note on which to end. Thank you very much indeed. That was a great session.