



UK Engagement with Space Committee

Corrected oral evidence

Monday 3 March 2025

3.30 pm

Watch the meeting

Members present: Baroness Ashton of Upholland (The Chair); Baroness Bonham-Carter of Yarnbury; Lord Booth-Smith; Lord Clement-Jones; Baroness Donaghy; Baroness Mobarik; Viscount Stansgate; Baroness Stowell of Beeston; Lord Tarassenko.

Also present: Lord Lansley; Lord St John of Bletso.

Evidence Session No. 1

Heard in Public

Questions 1—11

Witness

I: Professor Brian Cox, Professor of Particle Physics, University of Manchester

USE OF THE TRANSCRIPT

1. This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv.



Examination of witness

Professor Brian Cox

Q1 The Chair: Good afternoon and welcome to this meeting of the UK Engagement with Space Committee, our first public session. I am absolutely delighted that we have Professor Brian Cox as our first public witness; thank you so much for being with us today. We will go through a number of questions, which will be an opportunity for us to hear your thoughts and ideas and help to inform the work of the Committee. We anticipate the session will last about an hour.

I will kick us off; how would you summarise the benefits that we get from space science and exploration? There are lots of sceptics who think this is just a waste of money. You talk about this extremely eloquently. What would you say?

Professor Brian Cox: It might be worth giving a bit of wider context. I made a programme for the BBC, a little documentary, back in 2017, and I got to speak as part of that to quite a few of the big players: Jeff Bezos; Elon Musk; Richard Branson; and a lot of smaller start-up companies on the west coast of America. It was interesting because it felt to me almost like a gold rush at the time, and although it is not too long ago, a lot has happened since 2017.

Jeff Bezos said to me that in order to build his company, Amazon, he needed two pre-existing pieces of publicly funded infrastructure: the postal service and the internet. He said that given those he was able to build his company, and he wanted to do the same for entrepreneurs in the future in space—the on-orbit infrastructure, launch services and so on.

Both Jeff Bezos and Elon Musk—I interviewed Elon; we had an interesting conversation, but he would not be filmed or recorded, so it was not a lot of use for a TV show—mentioned that they have been inspired by two texts. There is a classic book from 1976 by O'Neill called *The High Frontier*, and they both mentioned it. In that book, O'Neill asks why we want to go to this frontier, and he said that, "there is reason to hope that the opening of a new, high frontier will challenge the best that is in us, that the new lands waiting to be built in space will give us new freedom to search for better governments, social systems, and ways of life, and that our children may thereby find a world richer in opportunity by our efforts during the decades ahead".

That was 1976, and to understand what is happening, particularly in the US, but around the world, it is good to understand where the inspiration came from. Someone else I met as part of that programme was Robert Zubrin, who is often credited as convincing Elon Musk that he should go into the space business. Zubrin is very forthright, and he has a very kind of frontier mentality. He has written widely. There is a quote from his book, which he said to me almost verbatim. He fixed me in the eye and



said: "The worst idea there has ever been is that the total amount of potential resource is fixed. It is a catastrophic idea because it sets all against all".

His position is almost that the cause of most, if not all, conflict historically has been this idea that resources are limited. Of course, we are well aware of that now; it is putting pressure on the earth's climate and the earth's ecosystem; resources are limited on the earth. But Zubrin, O'Neill and, by extension, a lot of the entrepreneurs who are in this business feel very strongly that this is the way that we expand our civilisation while—Jeff Bezos always emphasises this—protecting the earth, because, in Bezos's words, it is the best planet in the universe for us, which, self-evidently, it is because we evolved on it. That context of the inspiration is important.

We could look at what I was going to say was the more down to earth part. I am sure that throughout this inquiry you will talk about the economics, but it is worth just reflecting on that. There is a McKinsey report that came out in April 2024 called *Space: The \$1.8 Trillion Opportunity for Global Economic Growth*. That is a relatively reasonable, perhaps slightly conservative, report claiming that by 2035 the space economy will be worth something like \$2 trillion; so, we are looking at something like 9% or 10% growth year on year from now. I suppose to the sceptic you could point out that we are talking about one of the highest, if not the highest, growth areas in the world economy.

It is also worth pointing out that many people I have spoken to in this business object to us splitting the economy into the space economy and the earth economy, because it is, of course, the economy. It is a big part of our economy. To focus on the UK, I think the figure is that something like 18% of our GDP relies in some way on space, whether it be communications, earth observation, GPS and so on. It is already a vital part of our economy. I am sure we will speak about the 10 and 20-year horizons, but when we look at them, the opportunities become more O'Neill and Zubrin as we go forward in time and less just about economic growth.

Q2 **Baroness Donaghy:** You have argued in the past that Governments do not invest enough in the UK. Do you think that is still the case, and if so, have you got a view about what percentage of the GDP we should be spending on it?

Professor Brian Cox: The answer is yes. If you look at the numbers, the UK, at the moment, spends something like 0.05% of GDP on space. For comparison, the US is about a quarter of 1%. We are low; we are significantly below France and Italy, for example. When you put that in the context of what I just said about how this is, arguably, the fastest growing area in the world economy, or at least alongside areas like AI—it is one of the key growth areas—you would argue that 0.05% is low. Especially because if you look at the numbers now, the space sector is worth something like £18 billion in the UK, with 50,000 high-value jobs;



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so, for that very small investment we get a great deal back. You can then look at where you would increase that investment, but it seems that just on the basic number, we are below many of our major competitors and way below, as a percentage of GDP, countries like France, Germany and the US. It is clear that there is room for greater investment.

Lord Tarassenko: I have a related question regarding universities. Being a professor in a university which has a fair amount of space research, located not far from Harwell and Culham, I have a specific interest in the universities' strength in space. I want to salute you as still being an active professor at the University of Manchester. I have a minor conflict of interest to declare to the rest of the Committee in that my daughter studied physics at the University of Manchester and attended one of Professor Cox's lectures to the first years in 2010. I am inherently positively biased towards our witness today.

Professor Brian Cox: Is she still a physicist?

Lord Tarassenko: No, she works for a different industry: the animation industry and Aardman. She made a transition towards the creative industries, having started out in physics.

We believe in this country that our universities are world-leading in the fields of space manufacturing and space science. The evidence is that the last time we looked, which is about 2021, we had 53 UK universities with active space science research interests and 2,000 or so university-based researchers. You mentioned that the last time you were in front of a Committee was the House of Commons Science and Technology Committee in 2015, when the UK just about retained its position as one of the world's leading research bases. Given that you have highlighted already that our investment is lower than other European countries such as France and Italy, where do you think we are now for science and technology, specifically space technology or space manufacturing, space science and space technologies? We are obviously punching above our weight, but is what we are investing specifically into the university sector to support university space research enough?

Professor Brian Cox: It is a central question, because when we look at the opportunities that we have spoken about and are going to speak about, I see UK plc, if you like, as an ecosystem. There are world-leading, or at least highly competitive, parts of that ecosystem, and the universities sector is a necessary but not sufficient pillar; it is part of the foundation of this success; we cannot do without it. I think I probably said in 2015, and it is worth repeating, that a university sector like ours is easy to damage, but almost impossible to rebuild from scratch. Countries like China are trying, but it is a tremendous investment; so, it is extremely valuable and necessary.

If you look at the way collaboration works, I could list a lot of examples, but the James Webb Space Telescope is an important one. It is, obviously, one of the world's leading instruments, which is tremendously



exciting. We can talk about the science if you have got time. There are four main instruments on it, and we led one of them, an infra-red camera instrument. It was a consortium led by STFC/RAL, with Airbus and Leicester and Cardiff universities¹—I do not want to get that wrong. The key point is that you have the funding agency; you have an industry partner, in this case Airbus; and you have a list of universities that lead the construction, and they are an integral part of it.

As you mentioned, the university sector is under pressure. Maybe this is not the right place to go into the pressures, but even if you look at research, the estimate from Universities UK is that we have something like a £5 billion deficit on the research spend, and part of that comes from the full economic costing model. Of course, we have deficits as well in teaching; those are made up, in some large part, by international students; that is under pressure as well. We could talk about that in some detail, but the key point is that, in everything we talk about today, the way our ecosystem in space works is as a collaboration between our industry, our academic sector, the national laboratories and the funding agencies. It is extremely successful, but it is under pressure. To me, that would be the key message: there are several pillars here that are all necessary but not sufficient. If you damage one, the whole edifice can collapse.

Q3 Lord Booth-Smith: Taking all that you have just said, and thinking a little bit more about the specific context of the UK market right now and how it interplays globally, what do you think our structural comparative advantages are versus other similar nations?

Professor Brian Cox: Our very broad and deep research sector is one of them. If you look at our industrial capacity, an example of an extremely successful company would be Surrey satellites, which, very famously, initially grew as a spin-out from a university, which is extremely important as that tends to be where these innovative companies come from. It is now definitely world-leading in the construction of lower mass satellites, but if you look at the big programmes, it also played a central role in Galileo, for example, which is an extremely large European programme.

The sector is broad and deep. Another example would be our imaging technology and companies like e2v. It was recently taken over by an American company, but it manufactured the optical sensors for almost all the big successful space missions you could list: the Kepler space telescope; the Hubble Space Telescope, New Horizons—you could go on. Our technology companies have had a key role in many of those missions, so that would be the answer to your question.

Lord Booth-Smith: I am thinking more about the traditional sectors that I suppose the UK is a centre for—you may not know the answer to this

¹ The consortium was led by the UK Astronomy Technology Centre in Edinburgh alongside STFC/RAL, EADS Astrium and Leicester and Cardiff universities.



question, but it is more about if you have come across it—like insurance, finance or legal work. As a new frontier emerges, I would imagine that someone is going to try and create some sort of legal framework around it, and there is going to be insurance required in some way. I was wondering if any of the companies that you have seen, or any of the research you have seen, have people thinking about that, and if there is anything interesting happening in the UK in that space.

Professor Brian Cox: Yes. It is widely discussed. I think the UK insured the first communications satellite in 1965. It was Lloyd's, of course. It is a key point; we are very good at professional services. I have attended several conferences over the last few years. I was at one a few weeks ago in the UAE, which was discussing the legal and regulatory frameworks which must be developed as we begin to industrialise near-earth space and onwards to the moon; we will probably talk about asteroid mining. It is interesting to me that a lot of countries—Luxembourg is another one that has always been very big in this area—even if they cannot contribute technologically, although many have the ambition to, can contribute to regulatory regimes. These regimes are very old-fashioned really; we are talking about the treaties that were put in place in the Apollo era.

We will need to look at mining and mineral rights. I know the UK Space Agency is particularly interested in developing a role in space debris management. For example, say you lose contact with a satellite in this increasingly congested environment, there is then a possibility it will come into conflict with one of your satellites. What do you do? Who do you have to talk to? Is it the country that launched the satellite? Do you have the right to move it? Could it be considered an aggressive act if you move someone's satellite, even if it is not functional and threatening one of your pieces of infrastructure? Those frameworks do not exist, so I agree with you that putting the technology and academic work aside, our long history in legal services and so on could play a vital role—absolutely.

Q4 **Lord Tarassenko:** Coming back to Surrey satellites, what most people do not realise is that it has been around for 40 years; Elon Musk got a board seat from investing 10% in 2005. It may be an unfair question, but, in your view, why have we ended up with Surrey satellites, which was the world leader just 20 years ago, being acquired by Airbus at a much lower scale than what has happened since with SpaceX and Starlink? Was there anything that we missed doing? Did we not invest enough? Why is it that Elon Musk was talking to Surrey about understanding what they were doing and is now in the lead by several orders of magnitude?

Professor Brian Cox: It is a question that is asked often. It is one of the UK's oldest problems: the translation of our expertise into major industrial and economic success. You are asking a question that gets asked all the time about the UK economy, and I am not an expert in that field.



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Lord Tarassenko: I just wondered if there were any space implications for that. You are absolutely right; it is a question that is asked in multiple domains, but there may be different issues in different domains. Was there a lack of investment in supporting a company such as Surrey satellites 20 years ago? It is an amazing story, but it is a company that is quite mature, 40 years old.

Professor Brian Cox: It was one of the major players in Galileo, for example, which is the European global positioning system and which it has now lost as well. That was for a different reason—it was Brexit-related. I do not know whether we can say that if it had more support, it would have continued. You could argue, I suppose, that if there had been some kind of European programme to develop something like Starlink, Surrey satellites would have been well placed to play a major role in it. Maybe that is an answer. But then that goes back to what role we can play in the future in being in the decision-making process when these collaborations begin, or even be able to initiate such collaborations, for systems such as Starlink.

Q5 Baroness Mobarik: You have already mentioned that we have considerable strength in satellite manufacture. The city of Glasgow is the largest producer of satellites in Europe. How do you envisage the space economy looking in the future? What do you consider to be the key emerging opportunities in space for the UK? In that context, could you perhaps say something about the Moonlight Initiative?

Professor Brian Cox: It is a remarkable fact that Glasgow is the largest manufacturer of satellites in Europe. We tend to forget how successful we are in those areas. Also, talking about Glasgow and future scientific missions, one of the most exciting missions from my perspective is the LISA mission, which is a gravitational wave mission. The Nobel Prize was awarded a couple of years ago to Kip Thorne and others for work on gravitational waves. Glasgow has always been very strong in gravitational wave astronomy, which is used to detect, for example, the collisions of black holes.

You might ask: why is that important and why is that interesting? Some of the research into black holes is leading us into insights and transferable skills which have been found to be extremely useful in quantum computing, which is probably a bit off-piste. It is a very strange connection that the study of black holes would be important, potentially, for understanding quantum computing—another example of serendipity in science. LISA is one of the big European space missions, which Glasgow has a big leading role in. Your question was about economic opportunities?

Baroness Mobarik: Yes. How do you envisage future opportunities?

Professor Brian Cox: I mentioned access to resources right at the start of the session. We are talking about asteroid mining, and most people you speak to would say that is a medium-term goal—although it is worth



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reflecting on what is up there. One of the near-earth asteroids has more metal than the earth in it: reservoirs of iron, nickel, cobalt, gallium, platinum, a lot of the rare metals. On the potential, people are already talking about a \$1 trillion asteroid mining industry. You could ask: how can we play a role in that? It is a good question. Maybe I am skipping forward a bit, but it goes forward to our questions about our collaborations. Who do we collaborate with to begin to play a role in those areas that sound like science fiction, and perhaps 10 years ago or 20 years ago were science fiction? It is not a coincidence that a lot of start-up companies in the US are now asteroid mining start-ups that are at a \$10 million, \$20 million, \$30 million or \$50 million level. A lot of venture capital is going into those companies. Why? Because it is seen as a potential resource; not even a potential resource—it is a resource.

There are two things to say about it, though. When you read into it in more detail, the shorter or nearer-term goal in terms of access to resources in space is building things in space. There are two different economic arguments you can have about, or framings you can give to, resource access in space. One is whether we bring it back to earth. That is extremely expensive at the moment. Most economic studies that I have seen would say it is further down the line that you start to go and mine rare metals and things on asteroids and bring them back for use on earth. Initially, access to resources like water is central. It has been described as the basis of this economy that we are building in space.

The reason a lot of missions to the moon are concerned with surveying for water at places like the moon's South Pole is that water is the fundamental resource. When you have water, you have rocket fuel, you have oxygen and so on. Most of the studies on the next 10 or 20 years that I have seen are concerned with the technology to go and access resources that will then be used in space; and then, further down the line, when it becomes economically feasible, we will begin to bring those resources back. I hope that is an answer to your question. Asteroid mining is one of the opportunities.

Baroness Mobarik: Can you say anything on service industries and the Moonlight Initiative?

Professor Brian Cox: I mentioned at the start of the session the conversation I had with Jeff Bezos a while ago. It is interesting that Blue Origin seemed to be quite heavily focused on in-orbit servicing and then servicing from there on to the moon and the asteroids. On the development of the infrastructure—servicing and refuelling satellites, for example—it is worth pointing out, or remembering, that the Hubble Space Telescope would not be operational now if it had not been designed for servicing by the space shuttle.

I got the sense that Blue Origin, in particular, was very focused on providing infrastructure that entrepreneurs and industries can operate within and rely on. You are right. In the context of this committee, it



becomes interesting what role the UK could or should play in being a part of that infrastructure development.

You are going to have Tim Peake on the committee in a few months or a few weeks. I had a conversation with him, and he was interested in whether the UK plays a role in the construction of some of the space stations that are going to be part of that infrastructure. For example, could we begin to play a role in building modules for the space stations? We do not do that at the moment; it is not something that we are world-leading at in the UK, but maybe it is something we want to look at—whether the UK wants a part of that real estate in orbit. I suppose the way that I think about it, as Jeff Bezos said, is as the internet and the postal service of this new 21st-century economy. How much do we want to be a part of the development and management of the legal services, regulatory services and the physical construction of that infrastructure? That is an interesting question for me. Given the potential out there, I think that, over many decades, this is going to become not just one of the largest growth areas, which it already is, but it will become dominant at some point. The question of when it becomes dominant as part of the world economy is a good question, but it will. We have to be looking at playing a leading role in developing a framework for how that part of our economy operates within the global economy. It seems self-evident to me.

Q6 **Viscount Stansgate:** Between 1986 and 2009, it was the successive policy of UK Governments not to invest taxpayers' money in human spaceflight, preferring instead to support robotic missions. Looking back, was that wise?

Professor Brian Cox: It is a very good question. It depends through which lens you look at the decision. You could argue that if you are talking about engaging the public, which means having public support for investment of taxpayers' money in space, it is true that robotic exploration is extremely successful. Mars rovers, the Hubble Space Telescope—although that relied on astronauts to service it—and, going back in time, missions like Voyager are good examples.

It is also true that astronauts are tremendous ambassadors for the space industry. We have had two high-profile astronauts, Helen Sharman and Tim Peake, and it is hard to argue that they have not been tremendously valuable for the UK, not only in inspiration and education but just as valuable ambassadors. It clearly was a good investment. Going forward, if you are arguing about exploration of the outer solar system to acquire knowledge, the James Webb Space Telescope does not need astronauts to service it; it is not designed for that. Purely scientifically, you can make a strong argument that because it is so much cheaper, in terms of exploration, investment in robotic spaceflight is the way to go.

But now we are talking about developing an economy in space, human presence is absolutely essential to that. The answer to your question is that the terms have changed. I may well have been a supporter of the UK



investing much more heavily in robotic exploration if you go back 20 years, because then we were talking about, essentially, science or communication satellites and so on—that kind of infrastructure. But now when you talk about generating excitement in the UK space programme and the capability to do all the things that seemed like science fiction 20 years ago but now are not, it is essential that we get back into the human spaceflight business. It would be almost inconceivable for a country that aspires to play a leading role in this economy going forward to have no presence in human spaceflight.

Viscount Stansgate: I thank you for not only for answering my question but answering my follow-up question before I had a chance to put it, which was about looking ahead and how we should balance the demands of what we have invested in so far. I agree with you: the human element of spaceflight and the inspirational element is terribly important. I will not take up the committee's time, but, for the record, you will have answered both questions in one answer.

Q7 Baroness Stowell of Beeston: Professor, thank you very much for being here. I wanted to ask you about how you characterise the UK's commercial space sector. I have been struck by a couple of things that you have said in some of your answers. One was the comparison that you drew between the UK and France in terms of public sector investment percentage of GDP, and another was your answer to my colleague Baroness Mobarik's question about what is already happening in the UK commercial sector.

In characterising the commercial space sector, I am quite interested to understand how much you see it relying on investment from the public sector. If I compare space to AI, where the UK is behind France on public sector investment but is ahead in terms of our position in the ecosystem, I want to know if that applies in this context too. Is that public sector level of investment driving our commercial position, or are the two not necessarily connected, or not as connected as you might think they ought to be?

Professor Brian Cox: I am going to use the University of Manchester as an example just because I know it, but I am not trying to single it out in any particular way. I was there a few weeks ago, and it is looking at some of the spin-offs from the graphene discovery. I will make a couple of comments on that. One of the spin-offs was a company called SmartIR. It is a small company in Manchester's graphene innovation centre, which is a part of the university that houses small spin-out companies for new materials research. SmartIR is working on using graphene in thermal management of satellites. It just had a contract from an ESA business incubation centre, which is partly funded by STFC, the European Space Agency, Leicester University and the UK Space Agency.

I found it interesting that it is a relatively small company at the moment. If you think how it came to be—and it is growing fast—where did that capability come from? It came initially, of course, from the discovery of



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graphene by Andre Geim and Kostya Novoselov at the University of Manchester. Andre, in his Nobel Prize speech—I remember it really vividly—said that he discovered graphene in his playtime. He had playtime in the lab on Friday afternoons, and graphene was one of those purely blue-sky research discoveries but it has led to this multibillion-dollar industry and capabilities, worldwide and in Manchester, that we are world-leading in.

To be able to translate that ecosystem, where we have often curiosity-led academic discoveries and are then very smart about building them—Surrey satellites is another example of a spin-out from a university—is one of our strengths, although, as we mentioned earlier, it has also been one of our failings. But at the small level of taking, in that case, a world-leading materials science—and places like Manchester and elsewhere are undoubtedly world-leading in material science—and then turning it, initially, into small companies that can address fundamental engineering challenges in space science, that is what we are extremely good at in the UK, or at least we have the capability.

It goes back to what we spoke about earlier—the capability that has been built up over hundreds of years in our university sector. Making sure we invest and making sure that those discoveries that we make—and we are very good at making them—get translated, initially, into small businesses and then, hopefully, larger businesses: that is the key. I may be wrong here, but if I was to guess why we punch above our weight, I would say that that infrastructure we have, that collaboration on university campuses and elsewhere, is as good as I have seen anywhere outside of the US.

Baroness Stowell of Beeston: Do you think we are punching above our weight in a commercial sense, if you compare us to the same European countries that you highlighted before as being bigger public investors in this area?

Professor Brian Cox: A useful example is the European Space Agency, where, by design, you get out what you put in—the juste retour framework. In terms of space science investment, we are high as a percentage of that piece of ESA because it is based on GDP, and so, because we are one of the largest countries in terms of GDP, we invest a lot, and we get a lot back; and that forms the basis of a lot of our space science.

In terms of engineering, we do not invest in Ariane, the European rocket project, so we are extremely low investors outside of the space science area in the European Space Agency. One of the reasons I would give for why we do not have a big base for manufacturing, for example, modules for space stations in this country is because we do not invest in that part of the European Space Agency. There are different answers depending on which sector you are looking at. We are very good in space science—we put a lot in and get a lot back—but we are not so active in launch systems because we do not put anything in there.



Q8 Lord Clement-Jones: At this point, I need to declare an interest as chair of the governing council of Queen Mary University, because this is yet another university question. You have already unpacked quite a bit about the relationship between academic institutions and commercial space firms and emphasised the importance of that, but how can they do better? You have already said that we have a lot of assets as a country in this respect, but how could we do better, particularly with the spin-outs and setting up those innovative space firms?

You have illustrated the graphene example as a really good case. Are there others where we have not been quite so successful, but where, if we had had a different national policy or more ability to put resource in or had been less risk-averse or had a different investment pipeline, things might have been different? What would your prescription be for not only bringing the universities closer together with commercial space firms but having these successful spin outs?

Professor Brian Cox: It is not my area of expertise, but the Royal Society is in the process of preparing a report, and it said it would make it available to the committee as soon as it is published. I had sight of some of the research in that report, and one of the key findings was on stability of funding, in particular 10-year funding horizons, which I know has been discussed quite widely in government. Space missions take a long time to develop and, given that a country the size of ours cannot go it alone in any area of space research really—maybe in small satellite constellations, but broadly speaking, you cannot—being a reliable partner becomes extremely valuable. Very simple, almost accounting, changes such as 10-year funding horizons do not require any more money, they just require stability of funding, and the Royal Society identified that as one of the key things we could do, without requiring more resource, to make us a more attractive partner.

As a recent example, there was a moon mission—I cannot remember which one it was—where we developed an instrument. It almost did not get on the spacecraft because launch delays can push you outside of the funding envelope, and then you can end up having to return the money to the funding—you know the problem. That was one finding.

The other findings are the key recommendations which we have spoken about: maintaining a strong science and innovation ecosystem for space; and enhancing sustainability and security of the space domain through effective governance. Those were the key findings of that report; I think it is ready in a few months and will be delivered to the committee. We could talk about long-term funding stability and the relationship to ESA.

Lord Clement-Jones: Does any country do it better?

Professor Brian Cox: It is not my area of expertise, so I do not know.

Q9 Lord Lansley: You said earlier we should return to the question of who we collaborate with, so I will ask about that. First, how might we enhance



where our international partnerships are going in the future? Also, should we seek to develop partnerships that we do not presently enjoy?

Professor Brian Cox: I gave that list of missions that we have been involved with, with our sensors, in the past. It is pretty much every mission you can list: Cassini; Hubble; the James Webb Space Telescope; New Horizons. Because we are world-leading in certain areas, we collaborate with NASA and the European Space Agency extremely successfully. I have seen it in other areas, and in my area of research in particle physics it is the same. The US is a very valuable but difficult partner to base a strategy on because the funding is unstable; the partnerships can be unstable because of the way that their funding works with Congress, so you are vulnerable to political uncertainty. The difference between NASA and ESA is that if you are a major contributor to ESA, you are part of the decision-making process, and the more you contribute, the more say you have. Although, as I said, we contribute a lot to ESA's space science budget—I have the figures here—if you look at our contribution to ESA outside of that—to the voluntary programmes, if you like—it is extremely small. Germany is the biggest, and with France and Italy makes up something like 50% of the funding, and we are a very small part of that.

If you think about how the UK can play a major role in this economy going forward, the most reliable partner I see is the European Space Agency. That is just by design. If we were to up our funding to the level of France, Germany or Italy, we would be at the level of between half a billion and €1 billion, or something like that, per year. Those three have the major say in the development of policy and the return. The system is: if you put the money in, you get the money back into your industry. It is essentially an aerospace subsidy in any case.

Although it is clear that we have been extremely successful and will continue to be so because we are excellent at collaborating with not just NASA but countries like India, which has a big emerging space programme, and Japan, when you look at closing the gap in our influence in the decision-making process, I would look to ESA, purely because you have control over the decision-making process, which, clearly, you do not have with NASA.

Lord Lansley: I will make just two points out of that. Sometimes we talk about interests. My interest in this was over 40 years ago when I was a UK representative to ESA and the decision was made not to participate in Ariane and to get out of space transport systems. It was not technically "robotic missions instead of human missions"; the decision was to not be in space transport systems, and the intention was to put a great deal more emphasis on earth remote sensing and space telecommunications. Unless I am very much mistaken, there was considerable economic benefit associated with that.

Professor Brian Cox: It really worked.



Lord Lansley: Surrey satellites would be an example of the benefit from the participation in L-SAT that then went into Galileo. But do we have the control that we used to have in the European Space Agency? Can we exploit that in the same way that we did? We were in Galileo and now we are not, because it has shifted to being governed, essentially, by the European Union's space programme rather than by the European Space Agency. How might we overcome those limitations on what we do in ESA?

Professor Brian Cox: The colleagues I have spoken to who have worked within that framework at ESA point out—and it is probably stating the obvious—that because we are a relatively low investor, we do not have a terrific amount of say. Ultimately, it comes down, as with probably many things in Europe, to how big an investor you are. That is central to the discussion that we are having. If we accept that space is vitally important to the UK economically, in defence terms and on virtually every level, we have to be part of this. The earlier that we are part of it, the more say we will have, and the better we will be in 10 or 20 years' time. Then the question of where you can have influence becomes central.

For context, the budget of ESA is something like £5.5 billion, rising, I think, to £7 billion in a few years' time, so when you are talking about a reasonably low budget, a central question is: who do you collaborate with? Is it the right decision to collaborate, in a very successful way, with countries like the US, India and Japan where you will be a minor partner, certainly in decision-making, or do we aim to become a major partner in the decision-making process going forward? That would be my ambition for the country, but then the question becomes: how do you do that? It seems to me that ESA is a clear place where there is a clear path to increase influence in the decision-making process, because it really just depends on how much money you put in there. To pluck a number out of thin air, if we put €1 billion a year into ESA on top of what we are doing now, we would be the No. 1 funder.

Lord Lansley: In which programmes would you prioritise that?

Professor Brian Cox: It becomes a question, I suppose, of which programmes we want to push Europe towards that are in our interest. Ariane is an interesting one. I had a conversation about it the other day. You could argue that the technology is old-fashioned because they are not reusable rockets, and you would be right in some sense; it is not semi- or fully reusable, which is where SpaceX and Blue Origin are going. However, it was pointed out to me that the James Webb Space Telescope was launched on an Ariane 5. Why was it launched on an Ariane 5? Because it was a tremendously reliable system, and, for high-value payloads, the rocket is a small amount of money in the mission cost. That launch was so successful, so precise, that it extended the lifetime of the telescope because the rocket got it into exactly the right place. It did not need to use any fuel to adjust; it was positioned exactly where it should have been. So, you can argue that Ariane, although it is not the latest



reusable technology, is extremely good at some things, like extremely reliable launches, so that is a counterargument.

I suppose that, going forward, Europe will want a reusable launch capability; it has to. An example of an unfortunate failure would be the ExoMars mission. The mission was built; it is world-leading; the drill system is significantly better than anything that has been launched to Mars; but it did not go because we were reliant on a Russian launch vehicle, so we missed the launch window. The question we could ask is whether we are happy as a country in the current geopolitical environment, given that space is a key part of our economic and security future, being entirely reliant on third-party launch providers, or do we want to be part of the manufacturing and decision-making process? That is central, and I know what my answer would be.

- Q10 **Baroness Bonham-Carter of Yarnbury:** My question rather fits in with your first answer, which was so wonderfully eloquent about the frontier. We have always explored, have we not? Everything you said resonated with me. My question is about whether we are branding the opportunities of space correctly, but I have a prequel. There have been lots of questions about universities, and I am quite interested, being someone who is very involved in the creative industries, in whether you think enough is done at school level to educate and inform—sorry, I am not talking about the BBC – about the opportunities that space offers. Could I start with that? Then I have a supplementary.

Professor Brian Cox: The answer to that is no. In the Royal Society report that I mentioned earlier, 50% of companies in this area are reporting that they have difficulty recruiting. There is no doubt that if I give a talk, there is tremendous enthusiasm, and Tim Peake or Chris Hadfield would say the same; so, it is one of the drivers that drives people into careers in science and engineering. But transmitting to students that there is an actual possibility that they can personally be involved, and showing them the route and the road map, is the challenge.

As an aside, I am involved in a school with Lord Mawson, St Paul's Way in Tower Hamlets. One of the things we found when we started working at that school 10 years ago was that although, of course, there is no shortage of ability and ambition, it was very difficult for a student at that school to see a route to university, or an engineering apprenticeship, or whatever else it is, because they tended to come from families where no one had done that; so, it is an enormous barrier. For a student at St Paul's Way, if you do not know anyone who has been to a university, to consider going to the University of Durham, or Leicester—one of the central space science universities—it is a long way to go if you have no experience of it. The more effort we can put into tapping that talent, which is undoubtedly there, the better we will be. It is kind of an obvious statement, but you can see a gap there. The gap is obvious because something like half the high-tech companies say that they have trouble



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recruiting, so we clearly need to do something about that. What was the second question?

Baroness Bonham-Carter of Yarnbury: I have not asked it yet, but it is about the breadth of understanding of what space exploration offers. It is not just being Tim Peake, as much as we would probably all like to be him—except maybe for the motion sickness. There has not been a very good spreading of what space exploration actually involves and the numbers of people that it needs.

Professor Brian Cox: I think it is going to come. If you look at some of the road maps for companies—

Baroness Bonham-Carter of Yarnbury: You talked about modules; I was very interested by that. We should be designing modules, for instance.

Professor Brian Cox: We have not talked about the potential for on-orbit manufacturing. There is a company that I have spoken to briefly called Axiom, which is one of many commercial companies. It is developing modules and planning to build its own space stations. There was an investment just recently announced by NASA in four of those technologies, which are considered valuable. It is called the focus area 1a of NASA's research announcement, and this is all basically because when you are talking about structures, structural biology, crystal structures and semi-conductors, the microgravity environment looks to be potentially extremely interesting for drug development and so on.

The first technology was stem cell therapies; that was a collaboration with Cedars-Sinai Regenerative Medicine Institute in Los Angeles. The second was fabrication of flawless glass—that is photonics which is used for optical fibres. Another was biometric fabrication of DNA-inspired nanomaterials— so, again, in the area of biosciences—and the other one was a semiconductor crystal, so, advanced semiconductor manufacture. Those are the four areas that they are going to initially investigate in one of their modules. It struck me that those are all areas that the UK is extremely good in; we are excellent in them. We are at the research level at the moment, but it looks likely that the microgravity environment will be good for manufacturing, ultimately, and certainly research in those areas. Then the question is whether we want our own real estate there, or at least real estate that we have a say in, which would be ESA, essentially, because the Italians and the French lead in this. The construction company for Axiom is Thales Alenia. It is the European companies, Italian and French, that are manufacturing those modules.

On strategy, given that we want to be operating in these areas, the question of whether we just rent time or have our own real estate is a very central one. That relates back to your previous question in a way. I find that, obviously, students at school are interested in space, but they do not know that space can be biosciences, engineering, communications technology and all those different areas of expertise in the future—and



that is not the far future; it is just a few years' time. It will have a space component to it.

I strongly believe that we are talking about an ecosystem when we are talking about space. The space economy is not really separate from the economy, and the economy relies on this broad ecosystem. We have many of the foundations of that ecosystem here in the UK. It is perhaps not so difficult to solve the problem of how we can participate more in this multitrillion dollar economy because we have got all the bits. It would be very difficult if we did not have all the bits, but we do, and it is just about joining them up.

- Q11 **Lord St John of Bletso:** You mentioned the potential benefits of quantum computing. Clearly, its immense processing power allows us to handle complex simulations and calculations. I am wondering to what degree this leads to breakthroughs in cosmology and particle physics. In terms of what you mentioned earlier, would it give us a better understanding of dark matter and dark holes?

Professor Brian Cox: It is a great question. You have given me a reason to elaborate on something I said cryptically earlier. Research into black holes was really started by questions that Stephen Hawking raised in 1973-74 about, ultimately, information and black holes. This became a question of quantum mechanics, quantum information and quantum entanglement, which was very esoteric at the time, and, ultimately, has become a conversation or an investigation into the structure of space and time themselves, which is your question on cosmology.

One of the views of the structure of space and time is that they emerge from a network of qubits of some sort. There may be a description of the universe as a whole which looks somewhat like a quantum computer, which underlies the reality that we see. That is not to say that we live in a simulation but that it looks like there may be a deeper description of our universe. What is really interesting about that is that the skills that you develop as a theoretical physicist, PhD student, or post-doc are the skills you need to work in the quantum computing industry, because many of the challenges are the same. It is about quantum entanglement, which is a fundamental physics challenge but has become an engineering challenge.

It is one of the best examples of this ecosystem in action. We have been world-leading in fundamental physics for a long time, so we are producing people who can just step into the burgeoning field of quantum computing, quantum information and quantum devices. You mentioned dark matter, which is ahead of the potential in general purpose quantum computers, which might be a long way off. There are quantum devices for the detection of things like dark matter—particle detectors—but when you talk about detection, you can then start to talk about medical imaging. Using quantum devices for those applications is rather closer. Indeed, graphene and those modern materials are all inherently quantum



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devices. You need quantum mechanics to understand how those things operate.

Someone mentioned earlier that I was here about 10 years ago talking about funding in science. Government is relevant in space, and of course the Government would like to know where they should invest to get the best return; it is obviously a sensible question that you have to ask. But your question illustrates that, with research, it is almost like you are funding these little ants that are wandering around on the edge of the known and just making little, almost random, walks into the unknown; and quite often, or at least sometimes, the little ants stumble across something that is transformative; and, 100 years ago, quantum mechanics was a good example of that. But with those random walks, it is almost impossible to predict which little ant will stumble across a thing that transforms the world. You just have to have as many of them as you can and give them the freedom to wander.

Once you have done that—Andre Geim said this in his Nobel lecture, which we talked about earlier in the context of graphene—you have the responsibility, and you need the framework to take that knowledge and translate it into something that is useful for the benefit of society. You need both parts of your ecosystem functioning in order to be successful. To summarise, quantum computing and the skills that we need to take advantage of that potential growth area in the economy are vitally important. But they come from, ultimately, just making sure the whole ecosystem is healthy.

The Chair: Thank you. You have been very generous with your time for this public session. I will say formally that the public session is now concluded. Thank you so much, Professor Brian Cox.