



Select Committee on the European Union

Internal Market Sub-Committee

Corrected oral evidence: Brexit: Space

Thursday 15 March 2018.

10.05 am

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Members present: Lord Whitty (The Chairman); Lord Aberdare; Baroness Donaghy; Lord German; Lord Liddle; Lord Mawson; Baroness Randerson; Lord Rees of Ludlow; Lord Wigley.

Evidence Session No. 1

Heard in Public

Questions 1 - 8

Witnesses

I: Andrew Stroomer, Business Development Director Space, Airbus Defence and Space; Richard Peckham, UK Strategy & Business Development Director, Airbus Defence and Space, and Chair, UKspace; Dr Lucy Berthoud, Senior Teaching Fellow, University of Bristol and Chair of Space Universities Network; Stuart Martin, CEO and Executive Director, Satellite Applications Catapult; Professor Sir Martin Sweeting OBE, Executive Chairman, Surrey Satellite Technology Ltd (SSTL); Dr Chris Mutlow, Director, RAL Space; Professor John Zarnecki, President, Royal Astronomical Society and Emeritus Professor of Space Science, The Open University; Philip Davies, Chair of the Space Specialist Group at the Royal Aeronautical Society; Professor Alan Smith, Director Space Domain, University College London; Professor John Remedios, National Centre for Earth Observation.

Examination of witnesses

Andrew Stroomer, Richard Peckham, Dr Lucy Berthoud, Stuart Martin, Professor Sir Martin Sweeting, Dr Chris Mutlow, Professor John Zarnecki, Philip Davies, Professor Alan Smith and Professor John Remedios.

Q1 The Chairman: Good morning. This is a public session, so everything will be recorded and broadcast. The transcript will be publicly available and you will be able to check it. If members of the Committee have particular interests, they should declare them.

This is an area we have come into via the Brexit portal, but not all of us are experts on the space sector. As you know, some members of our Committee, Martin in particular, are experts in the area, and others, such as Jennifer Randerson, have become expert through the legislative processes, but most of us start from a fairly low threshold of understanding. We deeply appreciate all of you coming here and the expertise you bring.

We hope to conduct a relatively short exercise into the implications of Brexit for the space industry, space research and space science in this country, and, therefore, we can range fairly widely over the topic as compared with a normal evidence session. It would be useful if each of you started off by indicating your main concerns, your main priorities in the industry and what you think the Committee ought to know. If anything provokes us to ask you a question as a result of that, we will, but generally, I want everybody to speak before we go into the more general questions, if that is okay.

Andrew Stroomer: I am from Airbus Defence and Space. I look after business development for civil space activities in the UK, and I am the site director for the Stevenage site. I will start off with a bit of background about Airbus space activities in the UK.

We are a significant player in space in the UK. We have UK space activities with a turnover of around £1 billion, and we employ more than 3,000 staff across the UK, mostly at our main sites in Stevenage and Portsmouth. We have two main lines of business in the UK. One is a commercial and export business for telecommunications satellites; if you are watching satellite TV in the UK, you will be watching it through a satellite that has been built in Stevenage or Portsmouth. Alongside that commercial and export business, we have some very special science projects, including the Mars Rover, the Solar Orbiter—a mission going to the sun—and satellites that contribute to the study of climate change.

We feel that we are at the sharp end of Brexit. We are a very integrated European operation. Some of our concerns are shared with the wider aerospace industry and wider industry in general, in particular the movement of people—we have an international workforce—and trans-European processes in European business, so the customs control side of things is a very serious concern for us. That is fairly general and shared across different industries.

More specifically, we are directly involved in some of the European Union space programmes: Galileo and Copernicus. Right now, we are seeing some very immediate consequences in our role on Galileo. Our team in Portsmouth is the incumbent for the ground control system for Galileo. Galileo is based on a constellation of navigation satellites, and in Portsmouth we are producing the ground software that controls where all those satellites are in orbit, making sure that they do not bump into each other and that they have the right healthcare.

We are currently engaged in a tender for the next phase of the ground control segment competition. Due to the Brexit environment, the conditions of tender and the security constraints, we do not believe it is possible to sustain a lead from the UK for that activity. That is an immediate consequence, and we will be able to come back to that in some of the questions later on. That is a summary of our interest.

The Chairman: Thank you very much.

Philip Davies: I have been working in the space industry for 36 years, for a variety of organisations. Most recently, I spent 11 years working with Sir Martin Sweeting at Surrey satellites, and for the last four years I have been the managing director of a company, Deimos Space UK Ltd, based in Harwell, part of an international group headquartered in Spain.

Today, I represent the Royal Aeronautical Society, which is the world's only professional body dedicated to the whole aerospace community. It was established in 1866 to further the art, science and engineering of aeronautics. The society has been at the forefront of development ever since. I chair the space group at the society, where we have a variety of interests in things such as launch vehicles and satellites. We run events looking at things such as manned space, space flights, space tourism and various satellite missions.

I would like to make a couple of high-level comments on the questions you posed, and we can go into more detail later. At the very top level, there is mutual benefit for the UK and the EU in continuing to participate together in space programmes. There are benefits on the UK side. I think the argument has essentially been won in the UK. It is the Government's policy to continue in EU space programmes if possible. There is also benefit from the EU side, not only the financial aspects—we finance about 14% of EU space programmes—but we give the EU access to expertise and engineering skills that it would otherwise not have access to. We will elaborate on that in answer to some of the questions. We bring competition into the European space arena. Sometimes, the UK is the only competitor for a company, for example, in France. It would diminish competition in the EU space programme if the UK was not there.

At the moment, the urgent problem, although not necessarily the biggest, is Galileo. The combination of the fact that it is a security-related programme with the default assumption of the European Commission that the end point is that the UK will not be a full participant in the programme means that we are already losing work on Galileo. Andy has

already mentioned that, and there are other examples. The urgent problem is Galileo, because even if we come to an agreement in two or three years' time, by then we will have lost a lot of expertise. Jobs will have moved out of the UK. There will be other incumbents and it will be impossible to bring that work back to the UK. The urgent problem to solve is the fact that we are already suffering very badly in the Galileo programme.

Finally, the Royal Aeronautical Society has produced a detailed response to all the questions you have tabled so far. I know this is an oral session but, if you would like a written copy of that, we are very happy to send it to you.

The Chairman: We certainly would. Thank you very much.

Professor John Zarnecki: I am a professor of space science and president of the Royal Astronomical Society. Incidentally, I have to get one over on our colleagues from the Royal Aeronautical Society: we were founded in 1820. I am sorry for that.

The RAS represents more than 4,000, mostly professional, astronomers, space scientists and geophysicists. Unusually, our remit extends from the centre of the earth to the outer edges of the universe. Increasingly, we use space-based telescopes and other instruments to observe, either to look down at the earth or outwards at the universe, or we explore and we go to exotic places in our solar system.

Most of our work in space science is done through the European Space Agency—ESA—not exclusively, but probably 80% of it. To put it simply, ESA provides the spacecraft, the operations and the opportunities to observe and to go to interesting places, whereas the member states, the UK among others, provide the instruments, the scientists and the know-how to make the missions successful. In the UK, it is clear by any metric that we have been incredibly successful in exploiting those opportunities, whether it is landing on a comet, as with Rosetta in recent years, which I hope people remember, or observing the cosmic microwave background. There are many examples of great success with major UK involvement.

On average, we do that with 30% of our funding coming from the EU in the form of European Research Council—ERC—grants, and Horizon 2020 Marie Skłodowska-Curie actions. There are many ways in which funding comes to us to provide the infrastructure without which we would not be able to play the leading roles in missions. We feel that we will face a cliff edge in two or three years' time when the existing funding comes to an end. The future does not look bright in that context.

Finally, let us look at the next couple of years. We are launching a mission called BepiColombo, Europe's first mission to Mercury. Solar Orbiter, which has already been mentioned, will go closer to the sun than any spacecraft has been before. The James Webb Space Telescope, the successor to Hubble, has 20% European involvement. All those missions

have major UK involvement, technologically and scientifically. Looking ahead, we face a future where we will lose our leading position in the next generation of such missions because of the loss of funding.

The Chairman: Thank you very much.

Professor Alan Smith: I am from University College London. I am currently the director of its space domain. Until September, for the previous 12 or 13 years, I was the director of the Mullard Space Science Laboratory. I am a space scientist, and a systems engineer by DNA, I think.

UCL Space Domain is an interdisciplinary organisation, with economists, anthropologists, lawyers and all sorts of people coming together under the common theme of space. About a year ago, we held a workshop, with many people invited from the space sector, dedicated to consideration of the implications of Brexit. In a way, my comments are coloured by the outcomes of that workshop.

I will focus on the European Space Agency and the EU. As John mentioned, the European Space Agency has been an enormous benefit, both to space science and to the commercial space sector. No one I know would argue against that. The European Space Agency has two types of programmes. Its mandatory programme is largely its space science programme, which John was mainly alluding to, and which has a wonderful series of space missions. Its optional programmes, one of which is Galileo, are those which member states elect to participate in and fund. What each member state puts in as a contribution, it roughly gets back in commercial contracts, in a system called *juste retour*, which is a fundamental part of the European Space Agency's approach.

The European Space Agency has 22 members currently. Twenty of those are members of the EU and two are not, so there is an enormous EU influence. Moreover, the EU itself is a major funder of the European Space Agency. In fact, it is the largest funder. It funds 30% of the European Space Agency's £6 billion annual programme. I believe that gives the EU a disproportionate influence in the European Space Agency. Exit from the EU will mean that our involvement in programmes such as Galileo, Copernicus and others is jeopardised. That will affect us scientifically and, more importantly perhaps, commercially, because those programmes are major commercial enablers for the UK.

There is a short-term risk to our engagement in those key programmes and our benefit from them. There is also a long-term risk, because for many years the relationship between ESA and the EU has been rather tense. The EU has made a number of approaches with a view to absorbing ESA within the EU in one way or another. In 2004, an accord was made that set in place a number of mechanisms for aligning them. It has not worked very well. Many of the mechanisms do not exist or are not active. In the future, we need at least to consider the likelihood of a closer coming together of the EU and ESA. If ESA is absorbed into the EU, and our whole role in ESA is threatened, we should be very concerned.

At the moment, there is general consensus among my colleagues that in space the UK needs the EU as much as the EU needs the UK, but once Brexit has occurred, the EU, as ESA has in the past, will seek to remove that dependency. It will put in place schemes that reduce the dependency of the EU on the UK. Just as ESA has many schemes to reduce the dependency of the European space sector on the US space sector, there is a danger that the EU and ESA will have similar schemes to disadvantage the UK.

The Chairman: Could I ask a question from my ignorance about the way the schemes under ESA are funded? I understand that ESA is not an EU organisation and has differential membership and its own programmes, but is it right that, in relation to ESA, Galileo, for example, is paid for entirely by the member states of the EU?

Professor Alan Smith: Yes, it is paid for by the EU from moneys secured from national member states in an optional way; member states put in money, ESA runs the programme and the money is distributed back through contracts. Is that fair?

Philip Davies: As a point of precision, the R&D part of Galileo runs like that. When the EU wants to procure satellites, for example, ESA acts as its procurement agency under EU procurement rules, not under ESA procurement rules.

The Chairman: The procurement rules relate solely to EU members.

Philip Davies: When it is procurement rather than R&D.

The Chairman: But ESA itself is not bound in any sense just to go to EU facilitators.

Professor Alan Smith: If the EU is funding a programme, in principle it does not dictate how the programme is administered or implemented, but it has an enormous say in the matter. One cannot ignore its influence in that area. If the EU is funding Galileo, I believe it has the influence to say that non-EU member states shall not be part of the game.

Philip Davies: The EU set the procurement rules for how Galileo should be procured in terms of industrial policy and access by third countries outside the EU. That was all defined by the EU, and ESA had to follow those rules. It could not follow its normal rules. It had to follow the EU rules.

The Chairman: My noble friend Lord Liddle reminds me that that money, because it is specifically procured from individual member states, is not part of what we would normally say is the EU budget.

Professor Alan Smith: It is part of the £6 billion, but it is not part of the budget signed off by the Council of Ministers.

The Chairman: That is what I mean. Sorry about the diversion, but I needed to clarify it in my own mind.

Dr Chris Mutlow: I am the director of RAL Space, which is part of the Science and Technology Facilities Council, one of the research councils soon to be part of the UKRI. It has existed for 50 years, to keep the record straight.

The Chairman: The House of Lords has lasted longer than all of you.

Dr Chris Mutlow: The academic community, with government, acts as a national laboratory for the access to space. Increasingly, we are helping industry to deliver impact from its access to space by providing facilities that attract both industry and inward investment. As part of that, I am leading the build of the £99 million national satellite test facility that BEIS has just approved from the ISCF.

We have particular issues at the moment with regard to Copernicus. We have a number of contracts involving delivery of data services to the European Centre for Medium-Range Weather Forecasts that have Brexit clauses in them. We have some world-leading data centres that hold data. Once Brexit happens, those clauses will be enacted and we will no longer be able to be that data centre. There are punitive clauses whereby we might even have to pay for the transfer of what we have to some other organisation. In that sense, there are immediate issues that we are dealing with.

Equally, we are a builder of instruments for astronomy and for Earth observation. We too have landed on a comet. Many of the instruments that we are building are aimed at the Copernicus missions and delivering the datasets that our government and academic customers need to do their business. Being involved in those programmes gives the UK a lot of influence over the quality of the data that comes out. The concern is that in Copernicus, if we are not properly in, we will no longer be able to do that. Even if we can still get the data from other places, we will not have our current influence over the quality of data and the implementation of spacecraft and instruments. There is already evidence that, although we are still subscribing, agencies have an appetite to minimise the use of UK companies and organisations such as ourselves in doing that delivery, because of the issues they have already encountered on Galileo. There are some live issues for us.

The other issue, not just in the space domain in our organisation but across the board in all the other science areas, is that we require a lot of talented scientists, technicians and engineers. They are rare. Even with access to the European Union, we struggle to get engineers. We have been advertising some rolling posts. For a number of reasons, salaries in the UK look uncompetitive: there is the change in the value of the pound, and we are civil servants. We have seen a massive reduction in the number of people from the European Union applying for the posts we have. We can provide the numbers on that. In a post advertised pre-Brexit, through Brexit and post-Brexit, we have seen a big reduction in the number of applicants.

We were already struggling to get good people, and we have already seen an exodus of four or five people. We have about 260 people in my department. About 10% of them are from the European Union. We have seen five or six of them leave already because they do not understand what is going happen to them in the future. It is a live issue for us. We are trying very hard to deliver for the UK by supporting our industrial colleagues, and the Government are investing strongly in that area, but we are treading water and that is not helping us to move forward.

The Chairman: I might ask you to provide examples of what you call Brexit clauses. If you could do that in writing subsequently, it would be useful.

Dr Chris Mutlow: Yes, we can do that.

The Chairman: Thank you.

Stuart Martin: I am the chief executive of the Satellite Applications Catapult, one of a network of catapult centres that I hope you are somewhat familiar with. They were set up five years or so ago, so we have not been around for quite as long as some of our august colleagues, and they help to foster the development and use of emerging technologies in business, and hence create economic growth. Our catapult focuses very much on satellite applications, so at this point it might be useful to try to separate the issues that we are talking about into two areas: industrial issues related to building and procuring the system, and downstream issues more associated with the work of our catapult, including how data from that system is used and whether we retain access to the data, much as Chris was talking about, for science and for commercial applications. Those are two quite separate issues.

My background before joining the catapult was on the industry side. I ran the group that is now responsible for a number of the large security systems around Galileo, which I think are some of the systems where there is most impact. Indeed, some of your questions focus on those areas.

Focusing on applications and looking at some of the broader implications of Brexit, we all know that new policies and regulations will need to be introduced in the UK arising from whatever agreements we conclude during the Brexit negotiations. There is a real opportunity, as part of that, to appraise the technologies and the applications of technologies that will be used to derive the new policies and regulations. The space community has something to offer in those discussions. Engagement early on will help inform the discussions so that we end up with the sorts of policies that new technologies can support and help us to enforce. That is a role that the space industry and we at the Satellite Applications Catapult are ready to step into now.

The Chairman: Thank you.

Professor Sir Martin Sweeting: I am executive chairman of SSTL. I also have an academic hat in that I am a professor in the Surrey Space Centre. To focus on SSTL, we specialise, essentially, in the manufacture and operation of small satellites—highly capable small satellites—at low cost. Originally, this was a spin-out from the University of Surrey, now owned by our august parents, Airbus. SSTL has grown to about 550 staff. We are still based at Guildford. We have launched 54 spacecraft, and 98% of our business is export. Our export earnings are just under £1 billion.

On the EU and the impact of Brexit, I echo many of the comments made by my colleagues on recruitment and related issues. Our primary concern is the Galileo space segment. SSTL built the first Galileo spacecraft, which was critical in enabling the EU to secure the frequencies for the Galileo system for Europe. Had the satellite not launched on time, those frequencies would have been claimed by China, and Europe would not have been able to secure that essential resource.

Since then, SSTL has built, with our colleagues in OHB in Germany, all 22 of the current Galileo spacecraft, of which just over half are currently in orbit and operating. Recently, we won a competitive contract for a further 12 navigation payloads, against stiff competition from European industry. This has placed the UK at the forefront of navigation payloads. It is often not realised that the payloads for the entire Galileo system are being supplied from the UK. Brexit has already been causing us some pretty serious problems in the latest contract, for the next 12 of those spacecraft, with regard to the punitive penalty structures that have been introduced by the EC in the contract. We have had very good support from BEIS and the Minister in trying to mitigate those, so that we are able to continue with the contract and find some way of managing those potentially very punitive clauses.

That immediate concern is to some extent being managed, but our real concern is that we are not able to participate in the design and development of the next generation of Galileo systems. Given the expertise, experience and heritage we have in the UK, that will certainly be a big disadvantage to the UK and to Europe. The UK is already being manoeuvred out of opportunities to participate in the next generation. As mentioned earlier, the real danger is that, even if the UK negotiates a position to participate in Galileo, the die will have been cast; the industrial consortia for the next generation will have been established and, even if we were to try to re-enter later in the game, it would be an almost impossible uphill struggle.

If the UK were not able to continue in Galileo, the implications for the EU and ESA of changing the industrial structure to manufacture the Galileo spacecraft, would be, without doubt, increased delay, cost and risk associated with performance, and it would, I suspect, result in a significant loss of competitive pressure in Europe. On the other side, the EU also has concern about the expertise and loss of competitiveness it would experience.

The Chairman: Professor Remedios has just joined us. Welcome. We will come to you in a moment. We are going round the table with people's first take on the subject. Mr Peckham is next.

Richard Peckham: I work for Airbus, but I am here as chairman of UKspace, the space trade association. It is an elected position; we normally serve a two-year term leading the industry voice. We have about 35 full members and about 35 SME members in UKspace. We represent the whole span of activity, from prime manufacturing and manufacturing of spacecraft parts to satellite operations and the applications and services part, which is utilising space assets.

The facts and figures for the UK are fairly well known, but I will recap. We are an industry of about £14 billion per annum. We employ close to 40,000 people. Of our £14 billion turnover, £5 billion is export and, of the £5 billion, about 50% is to Europe. Europe is clearly a big market. We are a highly integrated sector around Europe; a lot of the UK companies are foreign owned or have sites in the UK as well as in Europe. Overall, most of that £14 billion is commercial work, so the biggest part of UK space is commercial and a lot of that is export.

The heritage of the space industry has been very much through the European Space Agency, which we have talked a little about. Although that body is completely independent of the EU, a typical European Space Agency programme involves work share, as you have heard, based on the *juste retour* principle. Goods and people move around with equipment, so we build a bit in the UK, it might go to Germany for testing and then to France to be integrated with a bit of the spacecraft. A UK team building a payload, for instance, will go with it, so they might work in Germany for two months during a test campaign, and then they might need to go to Toulouse on an integration campaign. Those sorts of things happen. There are a lot of Brits working across other EU countries.

Lastly, the EU itself is a major customer, as you have heard. You have heard quite a bit about Galileo and Copernicus, which are the big current programmes, but the EU is very ambitious in space. There are a number of future programmes already being talked about and on the cards. GovSatcom is planned as a secure communication system for government use across the EU.

Space surveillance and tracking is another area. The space environment is getting quite crowded. At the moment, we are quite reliant on the US to track space debris and active and dead satellites. China and other nations are doing the same. There is an ambition that Europe should have the same capability to track the space environment, as space has become very much a critical part of our infrastructure. It is recognised in the UK as critical national infrastructure. If satellites were switched off, the impact across the UK would be quite severe.

The UK brings a lot to its participation in Europe. It is obviously in everybody's interests—the EU 27 and the UK—that we should remain part of that. If we are denied access, there will be an impact on continuity and

capability from the UK. I cannot say that the UK has anything unique. Will the EU 27 manage without the UK? Yes, they will. It will cause delay and it will cost more, but they could do it without us, for sure, although it is not in their interests.

Unfortunately, the environment at the moment is very much driven by short-term industrial gain. The industrial lobby is very strong across the EU 27, so, although it might be shooting itself in the foot for later, it is hungry for work. A senior figure—I will not mention his name as this is on the record—described the environment as hyena-like at the moment. People are picking at the UK work share. It is like a feeding frenzy. There is an opportunity, and I am afraid other nations are not behaving very well and are trying to grab our work. Yes, it will harm them in the long term, but in the short term they are looking to take our work share. Unfortunately, at the moment it looks as if they will be quite successful and they will get quite a lot of that.

The UK has made very clear publicly that it wishes to remain in those programmes, but if we are pushed out before we even get to the point of negotiating the future relationship, the rationale for why the UK should stay in might have changed. Why should we spend 14% of the budget if we have already been pretty much pushed out? That is the sort of debate we will have to have.

The Chairman: Thank you very much.

Dr Lucy Berthoud: I teach space engineering to 200 students a year at the University of Bristol. I am also the chair of the Space Universities Network, or SUN. We meet at equinoxes and solstices. Just kidding.

The network is made up of 28 space universities, and our aim is to inspire and prepare our students to join the space sector. We do that through projects such as CubeSats, which are little nanosatellites, and satellite in soda can competitions; people launch rockets such as the one I have here, and a satellite pops out of the rocket and floats down, and they can communicate with it. We try to share best practice ideas such as those. We share resources and facilities and build links with industry.

On what is important to us, you have heard that there is a skills crisis in the UK in the science and engineering sector generally. The CBI reports that 40% of employers in the sector are finding it difficult to recruit. Universities supply the brilliant minds that we need for UK space. We think of the missions, build the space instruments and develop the new technologies that are vital for the satellites. We are a vital part of the UK space industry. High proportions of EU nationals work in science and engineering departments, including areas such as robotics, materials and AI, where there is not a sufficient domestic pipeline. That makes us really vulnerable to a Brexodus of top talent.

In the EU multibillion-pound funding programme—Horizon 2020—a quarter of the space funding comes back to the UK, which is a substantial amount. European talent and European cash enable us, in the

universities, to be world leaders in space research and innovation. We need continued access to Horizon 2020 and its successor, which is called framework programme 9. We already do extremely well out of the EU Marie Curie and European Research Council schemes, and many British staff and students get international experience through the Erasmus+ scheme. We know how desirable that is for these guys in industry. On behalf of universities in the space sector, we call for minimal barriers for all non-UK university staff and students working and studying here, and for UK staff and students to be able to work in Europe and beyond.

Can we meet our ambitious space sector target of 100,000 new jobs in the space sector, which is an exciting growth industry? It will all depend on whether we can make the UK attractive and accessible after Brexit.

The Chairman: Can we go back to Professor Remedios? You have seen what the score is. Tell us something about your organisation and your concerns.

Professor John Remedios: I hope you are not scoring our contributions. Thank you for your patience. I am sorry I could not be here right at the beginning.

I am director of the NERC National Centre for Earth Observation. NERC is the Natural Environment Research Council. It is the primary funder of environmental science in this country, at about £330 million per annum. Alongside our wholly-owned ships and aircraft, access to space infrastructure is one of the driving forces behind environmental science advances that have led, among many other factors, to NERC environmental science being the most highly cited in that science globally. Indeed, I believe its citation and referencing record in the UK is very high, if not at the top.

NCEO, as a national centre, is a distributed centre and university based, so we have both an institutional perspective, where we play a helpful role with government and with industry in supporting major initiatives, and an HEI perspective. I fund staff in 12 UK universities, including some of the primary ones. We have good insight into what is happening in the HEI sector in the world of earth observation, which is one part of the space sector, but a very important and growing one. Our job is not only to do our research, using our research expertise, but to champion that community, which is what I hope to do today and to explain what we get benefit from.

As others have mentioned, working in Europe over the last couple of decades has been a very important part of that strategy, not only in building the space sector in this country but in getting really good scientific insight to do programmes that we could not do any other way. Primary in that has been the European Space Agency, and we look to it for our research missions. Taking research instruments to operations is an exciting part of the story in which the UK has been one of the leaders. What we have discovered with our research missions is sufficiently powerful and helpful that other people want to use those instruments, so

it is a science to services, science to government policy and science to innovation route. We put great store by that, and the UK is very well respected for it. In fact, the genesis of the Copernicus programme, an operational series of satellites that I will return to in a minute, has its origins in UK and other European country research instruments that were launched in the 1990s and early 2000s. The question is how to continue them for other people to make use of them.

One of the interesting changes in science is that it is no longer just particular missions. There are astronomy missions that discover something very different and there are similar missions looking at our own planet. There are lots of things we do not know—for example, our recent perspective on the polar icecap. We can follow the news stories on that. It has been one of the most captivating stories for the public and it has real relevance. It started off as research: do we really know how ice works, do we know how ice and water interact and do we know what is driving the changes there? Having done that, it is clear that to understand those processes we often need long-term missions; one-off missions are part of the story and operational missions are another part.

For example, we work a lot with the meteorological satellites, the EUMETSAT series of satellites, which are built by ESA in the first phase and delivered for EUMETSAT in subsequent phases. That is another European programme, again not controlled by the EC, but very related to a collaborative team-working and research-driven agenda for operational systems, which brings us to Copernicus itself.

Copernicus, in my view, was, by design, intended to take those research instruments and make them sustained instruments for government and public benefit to provide commercial opportunity. You can reference studies that estimate, as best one can, the economic and commercial benefit from those systems. They remain a powerhouse for research. Research scientists from the UK are included in the very delivery of those systems. I have my own teams working in those systems to make sure that the data is top quality, so that it can be used for all those purposes. We are respected for that. It is not only the HEIs, but our colleagues at the Rutherford Appleton Laboratory, the National Physical Laboratory and the Met Office. There are substantial operations. It is a powerhouse for research that has been very important for us and which we view as continuing to be very important. A lot of our research is driven by long-term datasets. There is no other way to get those. We need to be part of systems that generate them.

For the UK, there is financial investment in those systems, via the EU at the moment, and there is intellectual investment. These systems are built around our capabilities. The UK has unique research capabilities in these areas. The systems will suffer in some areas because they will no longer be able to use our research capability if we are unable to participate fully in the programme. There is an irony in that story, in the sense that we would expect to be losing position in new projects in the Copernicus programme, which is different from the Horizon 2020 programme in that

it is more contract based. We have lost some position, but, interestingly, new contracts are still being awarded to UK-led groups because they are the best in the world at doing what they do. As I understand it, however, those contracts, some of which are being negotiated at the moment, have clauses saying that in March 2019, independently of any transition period, the situation will have to be re-examined. We are talking about a year away, which is quite a short timescale. There are jobs in the research sector that are based in these projects.

It is important to reflect on the budgetary aspect. One reason the UK is involved is that we cannot do these systems ourselves. There is no way. Well, you could always put the money in, if you like, but it seems unlikely that the UK would replicate the Copernicus system. Therefore, the advantages of that system are germane to what we want to do from the UK. A reduced budget will have consequences, because the system will have to be reduced or the other member countries will have to make up the money, which, presumably, will have some political ramifications. I do not want to go into the politics, but the system would either have to be made up with more money or be less capable, without some of our capability to help it.

We would also lose something that has been a real benefit. When I first started doing science, it was in the days when we had strong collaboration with the United States. I would like to see some return to that. I worked a lot with NASA teams in the early days of my career. We have done less of that, but we have benefited from very strong collaborative teamwork across Europe. We have made the best of the talents in all those countries, and that has been extremely important.

I close by saying that, at least for the Copernicus part and the earth observation part, we still see the European connection as vital for our health and for the quality of our research and very important in a research and innovation context, where we are trying to grow both government capability and industrial impact and vibrancy.

The Chairman: Thank you very much indeed. Could I ask Lord Rees to start the questions?

Q2 Lord Rees of Ludlow: Thank you very much indeed for the presentations. To structure the discussion, it might be best if we start with ESA and move towards the broader aerospace concerns. Within ESA of course, there are two parts: the straight science bit, which is formally independent of the EU, and programmes such as Copernicus and Galileo. Maybe I could start by asking about the ESA science programme. I am familiar with it and it is fair to say that it has been outstandingly successful. Indeed, it has been as successful as the NASA programme over the last 10 years. We think of NASA as being a far bigger organisation than ESA, but two-thirds of its money goes on a manned programme. In science programmes, Europe has been fully a match in scale, and indeed in quality, over the last few years, and we want to keep it that way.

We heard from John Zarnecki about the issues. If we focus on science in ESA, John Zarnecki said it would be a disadvantage if we were not in the ERC, Horizon 2020, framework programme 9 and the Marie Curie programmes, but those are really the same concerns that all science has. Is that not right? In that sense, there is nothing peculiar about space science, except that it is rather more international and there is, therefore, a far bigger lobby that wants to maintain our involvement in those three European organisations. Do you agree with that and do you have any glosses?

Professor John Zarnecki: Yes, the concerns are the same pretty much across the science and technology sector in that respect. However, I would suggest that the funding—typically 30% of what we get to support our space science activities—leverages an enormous amount, because, as I think several people have said, we pay in a compulsory amount, as does each member state, to the ESA space science programme. It is GDP related. There is no argument. It is totally formulaic. We leverage enormous benefit from that in getting what are called PIships—principal investigator roles—which are the leading scientific and technical roles on the various missions. That word “leverage” is important. The funding we put in either from national sources or from the EU enables us to gain enormous advantage in ground-breaking space science missions.

Lord Rees of Ludlow: If we were able to stay in the ERC and Horizon 2020 et cetera, do you think that, for purely scientific projects, we would still be more or less okay in our proportionate involvement in future?

Professor John Zarnecki: It is a big if, given the other issues that have been raised—mobility of people being the main thing. Yes, it is possible, but there are big ifs and buts along the way.

Dr Lucy Berthoud: There are some ESA statistics showing that the UK science return from ESA science missions is significantly higher with these PI—principal investigator—roles. For Herschel, we might have had 5% of publications compared with 17% of ESA publications on the topic. It is really vital that we keep those PI roles.

Professor John Remedios: The ESA science programme is related. It is the earth observation research programme. To back up that statistic, where we lead science missions or satellite missions, our publication percentage as a fraction is far higher. It is 25% of publications, and they are the leading ones.

Lord Rees of Ludlow: Going from straight science to the Copernicus and Sentinel projects, presumably we are going to lose out there, because they are partly funded by direct EU grants in a way that the science programme is not. To what extent can we manage to sustain our involvement in those very important earth-oriented observation programmes?

Professor John Remedios: I will make one comment and then hand over to colleagues, who I think will also want to comment. I would take

one perspective, which is to look at the next generation. We are already thinking about the next generation of Sentinel satellites. At least two, if not three, of the candidate missions, and in fact the leading candidate missions, have substantial, if not leading, UK capability driving their leadership. We are the people being asked whether they are worth doing, and we are proving scientifically that they are. If we are not able to do that, we are disadvantaged both in the EC and in ESA, where they are doing early studies of new missions. We are very concerned about that and very passionate about those missions, because they are good for our science.

Dr Chris Mutlow: I agree with John. As I said earlier, one of the things we have in Copernicus is the ability, by providing technical and scientific input, to make sure that we provide the kind of data and quality of data that our government and scientific users, and even some of our commercial users, want. As we are seeing, Brexit clauses are appearing and we are being squeezed out of things in practice. That will mean that our influence, which pays dividends for us, will disappear. I think you understated the issue with the explorer missions, John. If you look back historically across the explorer missions, a number of the successful candidate missions have been led from the UK. That will become increasingly difficult if we start to lose that capability.

Professor John Remedios: Could I illustrate briefly the sorts of issues we are talking about? They are quite fundamental to our views of the planet. The future Sentinels are about greenhouse gases, carbon dioxide, the changing temperature and polar change. The UK is renowned around the world for being expert in those things; we led the field.

Dr Chris Mutlow: They also hugely matter to us.

Professor John Remedios: Yes, absolutely.

Stuart Martin: I wanted to talk about the model that is at work between ESA and the EU. The research and development phase of the satellites, where we are talking about what the next generation of satellites might look like, is funded by ESA, and thus by subscription from member states. Irrespective of the EU situation, we can choose to become involved in that. When it switches to an operational system, and the EU decides that it wants to build and run those satellites for 15 or 20 years, it switches to EU funding. We could be in the perverse situation whereby we fund the product development and end up being excluded from the implementation and possibly, ultimately, the exploitation.

Interestingly, that is the inverse of a situation we were in some years ago with EUMETSAT, which has already been mentioned. There was a very similar arrangement: ESA would fund the research and development and EUMETSAT would fund the operational system. In that case, the UK was not funding the research and development, which meant that we had no expertise in the industrial base. When EUMETSAT was funded, the UK was obligated to fund the development through our treaty obligations on

EUMETSAT, and it all went to other nations. We are in danger of repeating history, but in reverse.

Andrew Stroomer: I have a very similar point. Taking that a bit further, industrial strategy decisions are very much driven by the benefits of having the operational system built by the company. To achieve that it is important to secure commensurate industrial roles during the development phase. In current circumstances, we may face a situation where operational roles under the control of EC, may not be available to UK. That could drive some of the industrial strategy decisions for the development phase, which could influence the role that we have in the early programmes with ESA.

Philip Davies: It is not a theoretical problem. It has happened in practice in the past. To take the example of Galileo, in the research phase, Canada funded the development of some of the equipment on Galileo before the EU had written down its rules on procurement. When it came to procuring the system, Canada was excluded from bidding on the equipment whose development its Government had paid for. It is not just a theoretical problem; it happens.

The Chairman: Are there any more points on this question?

Dr Chris Mutlow: Can I pick up what Stuart said? We have to be cautious about thinking that, because the research and development phase of these missions is funded by ESA, everything is okay. There is strong evidence that we are finding it difficult to get strong positions in those research and development areas at the moment, because people are concerned about locking themselves into UK suppliers. It is the problem that we already have with Galileo. Because of concern that they do not want to fund UK companies in the longer term, we are perhaps not getting the strong roles we might have expected through the funding we are putting into R&D. We have to watch that carefully and not just assume that, because we are funding that phase, everything is fine. It needs UKSA and other people to make sure that, on the ground, we are still getting those roles if that is what we want.

Lord Mawson: I am trying to get a handle on the money and how it works. I am very conscious of dependency cultures, and being dependent on government money, et cetera. I am trying to get a handle on what percentage of money from government, and the state, you are dependent on and what proportion of your finances is commercial and from business. Increasingly, with Elon Musk and others, we see a whole range of new opportunities in the commercial sector beginning to develop that are very dynamic, innovative and entrepreneurial. People such as me think that the future of this country is fundamentally going to be about innovation and entrepreneurship, and I am trying to get a handle on how fit for purpose your industry is for that move. You are already there, but what does it mean? How dependent are you?

Related to that is the question of talent. I have just been talking with one of my colleagues about this. I suspect it is all about talent. We have been

looking at the difficult question of visas and other difficult stuff, because in an entrepreneurial environment, if you cannot get the right people in the right place, you have a problem. From your point of view, what are the practical blockages? I suspect that both those things are related.

In recent years, I have found myself drawn back into university cultures. If I am honest, frankly I find them a bureaucratic nightmare. I do not sense that they are fit for purpose for a modern entrepreneurial culture, although I come across great scientists who are doing some amazing things. We all know that there are some disconnects. We need an honest conversation about where those problems are, and how we create an industry in the country that is fit for purpose, or the Elon Musks of this world, and others, will have a really big and important part to play.

Richard Peckham: Perhaps I can take an industry point of view. One remark I would make is: do not be fooled by Elon Musk and assume it is all privately funded.

Lord Mawson: I am just giving an example.

Richard Peckham: He does a fantastic PR job, and he is a fantastic entrepreneur. I would not want to belittle that, but the fact is that SpaceX is substantially funded by the US Government. He gets free factories built by the state, and NASA and DoD pay far more for launch than commercial people do, so he is publicly subsidised very heavily.

Space in general is changing and a commercial revolution is going on, which we are in a good position to exploit. We are doing well in the sector and we must not belittle ourselves, but relatively speaking we are still an immature sector compared with some others. Historically, it was pretty much all government; space was government. Inmarsat in the UK started off as an intergovernmental organisation—the International Maritime Satellite Organization—and is now a very successful commercial organisation. A lot of things started off as government organisations that then became privatised. Direct broadcast TV clearly drove the market, and that is now a very mature sector. The telecom market is pretty mature and commercial, and industry invests far more than the public sector, although public investment is important for early phase R&D because there are still long payback periods.

Generally, because space is still seen very much as a strategic asset by many countries, nobody should see it as a free market. China is funding its space industry very substantially, probably primarily for military reasons, but then there is all the spin-out. The same goes for the US and Russia, and very strongly for France. India is a huge space player. It is very much controlled by the Government and is not really open for export at the moment.

Lord Mawson: On the question about the proportion of moneys in your industry for which you are dependent on government and the proportion that is commercial and business-based, what are the rough numbers?

Richard Peckham: I mentioned the UK industry. That is about £14 billion. I would say that, of that £14 billion, between £2 billion and £3 billion would be government or institutional programmes in one way or other, EU and ESA, including some military. Between £2 billion and £3 billion would be government and the rest commercial. Going more into what we call the downstream—applications and services—that is much less dependent on public money. I guess the expensive infrastructure is still more dependent on it because there are long lead times, and often the person who invests in the infrastructure is not the person who gets the rewards. GPS is a fantastic example. The US taxpayer paid 100% for GPS, but the people who make the money from it, selling the chipsets, receivers and so on, are the industry, but overall, the US taxpayer has done very nicely out of it—thank you—because of the jobs and business it has created.

Professor John Zarnecki: Before I pick up the last point, I should say that I am now emeritus professor of space science, which means it is the pension scheme and not the university that pays my salary, so I can be entirely honest.

Can I give an example? Most people will remember the nearly successful Beagle 2 and my dear departed colleague Colin Pillinger, who developed a magnificent mass spectrometer of shoebox size to detect life on Mars. That seems pretty esoteric. However, it turned out that the technology he developed had lots of applications. It has already been used for in situ water quality monitoring, drug detection and air quality monitoring in nuclear submarines. It was a technology crying out for commercial application. You are right, Lord Mawson. My old university, which I think is typical of many, was completely unfit for purpose in that context. It is only because of the bloody-mindedness of a couple of my colleagues that a couple of commercial spin-out companies are now exploiting that technology. It is perhaps a little bit to one side, but I support what you are saying. We have enormous opportunities.

Lord Mawson: To pick up the talent point, unless our universities and industries are more entrepreneurial in their culture, they will not attract the talent that some of the commercial and other entrepreneurs will. Some of those people have very large budgets, so that may increasingly be the case. If competing globally is about talent, and I suspect a lot of it is, ultimately our universities will not attract it unless their cultures absolutely become more about that, or is that unfair?

Professor John Zarnecki: I think that is fair. Of course, some are much better than others at doing it. Many universities developed in a different era, so there is a lot of work to do.

Dr Lucy Berthoud: Many universities have innovation centres now. We constantly have build-your-own-start-up hackathons going on within the university, so there is an entrepreneurial spirit. Many of my students want to do start-ups rather than go into big industry. That feeling is there. We are all excited by that entrepreneurial spirit, especially in the space industry, but we have a problem in that we are haemorrhaging

talent at the moment. We are losing EU staff, and we have to clarify the visa situation. We need a low-cost and efficient visa system that will work, so that we can recruit and retain the best in the world.

I do not want to be a moaning remainder, or remoaner as I have heard they are called. There are some opportunities. We should take the opportunity to: try to fix our leaky skills pipeline and encourage more people into science and engineering; talk to teachers and parents; get employers, such as the guys on this panel, into schools to help with careers guidance; widen participation; get more BAME and girls into engineering and science; prevent people dropping out at universities; and, once they get into industry and research, help them to stay there.

Professor Alan Smith: I would like to pick up a couple of points that have been made. I do not know whether you have come across a book by Mariana Mazzucato called *The Entrepreneurial State*. She is part of our space domain at UCL. That book explains how Elon Musk got funded. More importantly, it explains the role of the state in creating an environment where entrepreneurship can thrive. Our problem is creating the breakthrough technologies. Creating breakthrough technologies is not something that venture capitalists normally pay for; it is something that the state pays for and then it evolves from there. That is the model.

Something else Mariana is very keen on, which relates to what Lord Rees said earlier, is mission-oriented industrial strategy. Rather than sectorial industrial strategy, which might be strange given that we are talking about the space sector, it is more about industrial strategies based on the mission concept. Space has been doing that since I started 40 years ago—I had to get a date in somewhere. We do missions where scientists, a plethora of different engineers and all sorts of other people come together in a very international way. The point I mentioned to Lord Rees is that the thing that is a bit different about space is the size of the international consortia that come together to make things such as satellites.

Yesterday, I returned from a meeting in Madrid on the Plato programme, where there were about 180 people, of whom 10 were Brits. The rest were from another 18 countries across Europe, all coming together to build a satellite to detect planets around other stars. It is an enormous endeavour, a £600 million programme. All sorts of things spin off in all sorts of ways in such programmes, such as the mass spectrometer on Beagle. The state has an important role in creating a basis on which we can build.

As far as universities are concerned, given that this is being recorded, I decline to comment on UCL as a university. What I would say is that UCL, like many universities, gets it; it understands where it has to go. Of course, it is easy to know where you want to go, but you have to get there. It is a journey that universities have to make. They are trying to make the journey, but you have to bear with them a bit, while the legacy culture, shall we say, eases away.

Andrew Stroomer: I have a quick comment on the practical point about delivering business. We benefit from the inspiration of the space industry anyway and we are really lucky that we can attract people to come, whether it is to work on science missions, entrepreneurial projects or telecom satellite delivery. What is important is being able to leverage between institutional support, the classic very inspirational science missions and the commercial export programmes that we have in telecoms. We work very hard at that, and I think we are quite successful.

We can take people who are inspired to come to the business to work on the Mars Rover and turn them into practical delivery project managers on the telecom side. There are technologies that go between the two, and there is feedback the other way as well. We can take the process-oriented telecoms business back into the European Space Agency world and be more efficient in the delivery of the science programmes. It is the balance of those two activities that makes the holistic business.

Professor Sir Martin Sweeting: To step back from Europe for a moment, one of the things I have observed when talking to many of our international colleagues outside Europe is a rather interesting side-effect of the Brexit position. Many other nations are now looking at us and saying that all of a sudden the UK has come to life. Before, they had a vision of us as mostly harmless, and perhaps rather comfortable in our position, but suddenly the threat of Brexit, from an external perception, has galvanised government and industry to say, "We can't rely on Europe and we have to start talking about other forms of relationships, bilateral and multilateral, beyond Europe, and engage with folk where perhaps up to now we have not been terribly active". The very clear message to me is, "Goodness, the UK has woken up", and there are lots of interesting things we can do. Elon Musk was mentioned. He started his space career with a small shareholding in SSTL and went on to earn much more money than I did.

Lord Wigley: Is the consensus opinion outside that the possibilities away from the EU can make up for the losses we will sustain as a result of leaving? Is that the implication of what you are saying?

Professor Sir Martin Sweeting: I am not sure that it has in any sense been quantified in that way; it is just an observation from colleagues external to the EU countries who say, "Goodness, we've seen the UK stand up and be far more active than we've ever seen before, not just in space but across the patch". Obviously, my area has been in space. Whether or not that has the opportunity to balance the books it is far too early to say.

Philip Davies: If you work back on the numbers, the UK is currently receiving money on the EU space programmes of around £200 million per year. That is a substantial sum to try to make up through other sources. I think it will be extremely difficult, given that we are already not ignoring other markets. Using Martin as an example, he sells satellites in Russia, China, Kazakhstan, Canada and the US. It is not that we are not exporting, but to make up a £200 million shortfall will be extremely

difficult, and if we do not do that, it will represent a contraction of the space industry in the UK.

Q3 Lord Wigley: The question I intended to ask feeds into that. Are the Government's planned investments in the UK space sector—spaceports and a national satellite testing facility—enough to mitigate the potential negative implications of Brexit?

Philip Davies: They are very welcome. It is really good that the Government are doing that. The spaceport programme has been massively supported by the Royal Aeronautical Society. We think it is a great thing for the UK and opens up a whole load of benefits, especially in the new space being talked about now, which is primarily about launching small satellites from the UK. We think they are great initiatives. The whole industry will be very happy to have really good facilities at RAL that are easy to use and located in England.

To go back to the numbers, the benefit of that national programme will still be a lot less than the £200 million we get from the EU programme. Unless we have a national programme of that size, it will represent a contraction of the industry.

Richard Peckham: To address both points, opportunities outside Europe have always been open to us. There is no closed market. Being a member of the EU has not precluded us doing anything outside the EU. Airbus, which I work for, sells its telecom satellites to Indonesia, Korea, occasionally the US, which is a pretty closed market, and Canada. It has always been an open market and there are no constraints. I agree with Martin that, as regards our mindset being comfortable in Europe, the industry is being forced to look a little more broadly. Having the Department for International Trade means that the Government are now more committed. Those things are positive, but they could have happened anyway; it is not that we can do something now that we could not do before.

On the question of whether the UK is doing enough with the investments it has made, from an industry perspective it is not enough, so the investments are welcome. The passing of the Space Industry Bill yesterday puts enabling legislation in place that, hopefully, allows space flight but also, because a commercial revolution is going on, puts some flexibility into the old Outer Space Act from the 1980s to take account of the way technology is going, with big constellations of satellites and so on.

We have set up a space growth partnership, comprising industry, academia and government users, and we are coming forward with proposals. As part of the Government's industrial strategy, we are proposing a sector deal for space. One of the things we are recommending would be with or without Brexit. If we end up with a hard Brexit and out, we will need to look again at what we are proposing, but at the moment part of the sector deal is that we want to remain in the EU programmes but that the UK should set up a national programme.

There is some real opportunity, but it is about leverage; it is not about more public money and becoming more dependent. There is real appetite from private investors and private equity. There is now a lot of private finance available, so there is a big appetite, but often it needs a little bit from government, perhaps legislatively or financially, to make the right things happen and enable that inflow of money. The timing is good, but we are looking for the sector deal, hopefully quite soon; we are in discussion with BEIS and we hope it will be imminent.

Q4 Lord Liddle: Can I shift the conversation to Galileo? I was advising the Government at the time the decision was taken to participate in Galileo. I remember it being very controversial inside government at the time, because the programme was seen as a statement of European identity. Some people thought that the Americans would not like that and, therefore, we should not do it, but we did it. To what extent will the view that it is about building a specifically European capacity inhibit our participation in future, if people think we are drifting off into the mid-Atlantic?

Andrew Stroomer: It is one of the rare cases where the European Commission sees itself as owning an asset, which puts it in a slightly different place from a number of the other debates going on. It is seen as somewhat of a special protected area because of that. There is also a wrapper around it of security constraints. It means that, effectively, the security constraint element is set so that the UK is treated as a third country and is outside it, which means that we cannot get involved in those kinds of technologies and elements of the programme. The conditions of tender for the next phases of the Galileo development make it very difficult for us to play.

You are absolutely right; the mindset at the back of it is that it is a very symbolic European programme, and therefore it is very difficult politically to see the UK being part of that. Over time, that might change. Over time, there are definite benefits to the EU of the UK staying part of the programme, because we have a lot of useful competencies and expertise in the programme. The issue, as I think we explained earlier, is that the timing, with these competitions coming up, may be such that we are not able to re-establish long-term participation, and it is compromised by the short-term decisions being taken in the programme right now.

Lord Liddle: Do we have anything positive to say about why we should participate, other than that we have lots of excellent capabilities that the EU would be foolish to ignore?

Philip Davies: Can I make a point on the UK Government use of Galileo? I remember the time you were talking about, when the UK Government were a bit ambivalent about whether Galileo was a good idea. At the time, the MoD was not particularly keen on Galileo. Some people were even anti-Galileo. That has all changed.

In the 2015 security and defence review, the MoD embraced Galileo; it intends to use it and to support UK industry in Galileo. To do all of that

needs the UK to be at the heart of the system; we need to be involved in the security. The moving of the security centre from the UK to Spain will be seen as a very bad signal for our potential government use of Galileo in the future in the public regulated service, which is the service restricted to qualified government users. The MoD would be using that service in its receivers.

The Chairman: To put it the other way round, and using Lord Liddle's phrase, is there the option of drifting to the mid-Atlantic? Earlier, somebody said that there used to be a lot more co-operation with NASA and the Americans, relatively speaking. Is that option available to the UK industry, without getting too political about the immediate political situation in America? Is it possible in the long term?

Richard Peckham: Generally, it is not. Obviously, we can co-operate with the US but we are a minnow, and we would just get the little bits the Americans do not want. We tried to co-operate on GPS. At one time, the US said that it would open up the next generation, GPS 3. At Airbus, we teamed with Lockheed and Boeing on different bids, but when it came to procurement it was, "No; it's going to stay US; we are going to do everything with US industry".

The United States has applied to the EU for permission to have access to the public regulated service. There are four global navigation systems: Chinese, Russian, European and US. The Americans realised how dependent they had become on GPS, so they wanted an alternative. They were not likely to rely on either a Chinese or a Russian system, so they embraced Galileo and that changed. Norway and the US have now both formally applied to the EU for access to the public regulated service, which is interesting.

Lord Mawson: That is why I find this conversation slightly difficult. In the modern entrepreneurial culture, it is not about size; it is about the detail and quality of what you are doing. If we are really good at innovation, developing new technologies and commercialising that stuff, and if we have the right talent, they will come to our door. Some of us think that the UK has an odd culture and history that is sometimes quite good at that kind of stuff. It is a question of mindset, which has come up a number of times in this conversation. Do we have the right mindset? We know that in the modern digital age very small things quite quickly can become really big things if you have the right drivers, the right mindset and you get the right people in the right room. They could come from anywhere in the world. It is about whether we are open to those kinds of things.

Philip Davies: The UK built two really good industrial positions where we were going to exploit the Galileo security service around the world. The software company CGI developed a lot of the Galileo Security Monitoring Centre, which is now moving to Spain. It had a business plan to exploit that around the world. QinetiQ is at the heart of that, with its receiver technology; it was going to do the receivers and the services for applications for Galileo security around the world. If we do not have full

access to the security part of Galileo, we lose the ability to do all of that work, irrespective of whether or not we have entrepreneurs. We need to be inside, as part of the programme, to do the commercial exploitation outside the programme.

Stuart Martin: We are an institution that has been set up to try to encourage and embrace entrepreneurial culture and bring it towards the space sector. To a very large extent, that whole environment has transformed over the last five years. There was not much of a start-up culture in space five years ago, to the point that when we wrote our original business plan we had no companies to talk about and we had to make up fictional case studies. Now we have about 80 companies based at Harwell and, overall, about 500 organisations where we are routinely involved.

When we talk about emerging technologies and entrepreneurialism, it is tempting to think that, if we get the right products to market, somehow they will find a way and things will take off, but very often there are impediments on the demand side that stop that happening. That is particularly the case in the space industry where procurement decisions for a lot of the institutional programmes are made at a political level. They have nothing to do with where technical competence exists.

In my introductory remarks, I mentioned that I worked at a company that was involved in bidding for some large components of the Galileo system at that time. Although we were at one stage quite favoured and well positioned in the competitive process, a piece of paper signed by Messrs Berlusconi and Schroeder stopped us in our tracks. That was it; we were out of the competition. It is not just about the entrepreneurialism and technology you can bring to bear; it is a complex landscape, and there are forces on the demand side of the market as well as on the supply side that have an impact on our ability to be successful.

Q5 **Lord Wigley:** Could I take half a step back? Before you have a product going to market, you need the R&D in place, do you not? What is the feeling about the implications for UK space R&D if we are no longer able to participate in Horizon 2020 or successor programmes?

Dr Chris Mutlow: One of the things we are doing now is exploiting stuff that we developed 10 years ago. Looking at the stuff coming into the commercial market now, our industrial colleagues are exploiting things that we had in the research domain 10 years ago. Anything that affects the ability to get money into research and development is a major issue. There are a number of good initiatives, such as the UK Space Agency. In the earth observation area, there is the Centre for Earth Observation Instrumentation, which is allowing us to develop some of the underlying technologies. Anything that damages the ability to get money into developing R&D will not affect us immediately but will affect the things we need to have in place in future underpinning it.

Professor John Remedios: For my centre and for our HEIs, there will be a direct impact straightaway, in April 2019, if there is no budget

agreement. If the budgets that go into the EU and come back to the research base disappear, it is a straight equation: there are fewer people. You are sending a message to the university talent pool that there will be less research. You are sending a message to potential undergraduates that there will be less research. In Copernicus, which is not a Horizon 2020 programme, the research base and my staff get money to prove our research capability, building on stuff that we have done over the past decades. Unless the Government decide to divert that money to a space programme that also supports the research base, there will be less money straightaway.

John Zarnecki made a very important point about innovative technology. It is not enough just to talk about the idea; you have to get it into space. It is no good if you just talk about it as a diagram. I agree that there is greater international interest in what the UK is going to do, but what I clearly see is, particularly, institution of government coming to the UK and saying, "You partner with us. What would you do?", then we have to confess that we do not have the money to do anything. They turn away very quickly, I assure you. They are real people who do real projects and put things in space. They want to know what the UK is going to put in space with them in partnership or by itself. That is capability. We have to have a government-supported industry programme that does that.

The Chairman: We are running out of time and I want to raise a range of subjects, so could you make your points reasonably briefly?

Dr Lucy Berthoud: A really important point is that a reduction in the possibility of EU funding will act as a disincentive for recruiting. We need access to international networks that are developing areas that are critical for us, such as space robotics and electric propulsion. That is where the EU is putting some of its money to fund exploratory space research. Of the current EU Horizon 2020 space calls, €53 million is coming back to the UK, so that is what we will lose.

Professor Alan Smith: I want to turn briefly to the point about entrepreneurship and the need for access to the fundamental R&D that is going on across Europe. It is not enough just to be good entrepreneurs; you have to be able to see the new technologies as they are being developed and be part of the community developing them. Any barriers between us and the huge amount of activity in Europe will marginalise our ability to be entrepreneurial.

Professor John Zarnecki: I have a simple addition to the simple equation John mentioned a few minutes ago. As a nation, we put £X into Horizon 2020. As I think Lucy mentioned in passing, we are incredibly successful at exploiting that fund. We get back 1.5 or twice £X. On paper, it looks as if we are putting in £X. If we get £X back after we have left, it still represents a significant loss; it is the cost of having been so successful in recent years.

Q6 **Lord Aberdare:** Have we sufficiently addressed the potential national security implications of the space sector? We have talked a lot about R&D

and the commercial opportunities, but until Lord Liddle's question I thought there was a potential extra dimension, which is that it matters from a national security point of view that we have capabilities that we may lose or that are under threat. Is there any argument that we have not covered relating to the value, from a national security point of view, of some things we currently have and that we may potentially lose?

Dr Chris Mutlow: Copernicus is delivering things about food resources and managing environmental resources, which are critical. That is one area. There is obviously the military communication side, and I am sure that others can comment on that.

Richard Peckham: The UK Ministry of Defence operates its own telecommunication satellites. That was a national procurement. It is a sovereign asset and the MoD runs its own communication services. Earth observing is another key security dimension. We have no sovereign capability in earth observation; the UK relies primarily on its relationship with the United States, or just gets commercial data. There are commercial companies, including Airbus, which operate their own fleets of satellites, and there is US equivalence in satellite earth observation data, so data is commercially available.

We talked about navigation, which is the other key strategic military asset. GPS has been primary for a long time; part of GPS is reserved for the military. The military has concluded that access to Galileo would help because we would get GPS plus Galileo, which gives more capability, but we would need access to the public regulated service I mentioned earlier. The US has applied for access.

There are new things such as understanding the space environment, space surveillance and tracking, where the UK would have the capability to do it itself, but it would be very expensive. That is the sort of thing you want to do in partnership if you can.

There is no direct national security implication from coming out of the EU, apart from the Galileo PRS, which is the most obvious one. I would say that elsewhere we are comfortable. We might have to pay more for certain services.

Dr Chris Mutlow: We have great capability in space situational awareness; we support Fylingdales and other places with characterisation. That is funded by the European Union under the SST programme, as is space weather. The loss of GPS timing would be a massive threat to government infrastructure. The UK has expertise in that; we support Met Office forecasting, and there are all the weather forecasting capabilities.

Lord Aberdare: All the different sectors we hear from are having problems with skills and talent; many are having problems with access to and participation in European programmes. What will give you an edge in persuading government that you are a sector with an extra requirement?

Dr Chris Mutlow: We need to sort out the visa programme. If we are not going to be able to recruit European nationals, we have to be able to recruit from other places. Currently, we have people stuck in the queue unable to get through because we are not paying sufficiently for the skilled talent that we need.

Lord Mawson: Why are you not paying them sufficiently?

Dr Chris Mutlow: Because there is a quota. You can jump the quota if you are paid more than a certain amount. Unfortunately, we do not pay that amount of money.

The Chairman: We have only a quarter of an hour left, and my colleagues have three or four questions to raise that relate to more immediate or specific issues. Perhaps they would put them in sequence and then anybody can comment.

Q7 **Lord German:** I want to bring us back to the here and now and the uncertainty we have been talking about. Is the uncertainty hindering commercial investment in what is going on at the present moment? In addition, as a result of something said earlier, what is the impact of losing ground control for Galileo in Portsmouth and the Copernicus data centre? I do not know where that is, but, if we lost both of those, are we talking about jobs, investment and the future? Roll that into one.

Lord Aberdare: My question follows on from that in a way, and refers to the commercial organisations in the field. What contingency plans are UK space firms making for different scenarios? Specifically, what are your plans if there is a no-deal scenario? Is there a deadline by which you need to know how the future is looking? Would a standstill transition period help to allay concerns or delay the need for a cut-off?

Baroness Donaghy: My question is about customs controls. If we were to have greater customs controls, what do you think would be the impact on space industry exports and supply chains?

The Chairman: Perhaps the witnesses could come in either on all those points, or on just one of them.

Richard Peckham: To start with an industry perspective, I cannot put a number on investment decisions, because I am hearing mostly anecdotal things. The answer is definitely, yes, people are putting things on hold; they are waiting and seeing. I hear from a number of my industry colleagues that they are holding on to the decision a bit longer. There is an impact, but so far I have not heard of any negative decisions, in the sense that people have said they are not going to invest in the UK but somewhere else. At the moment, they are just delaying and putting on hold.

All companies are having to spend money now on some sort of contingency planning. People are definitely contingency planning. I do not know how many man hours are involved for Airbus, but a lot of people are having to look at a lot of things. Generally, we have very few experts

in imports and exports, so even a big company is suddenly looking around for experts who can help, who understand the WTO and so on. People are still hoping for the best, so the big money is not being spent. A transition would definitely help. If there is to be a hard stop in a year's time, we have to hire people now to manage things such as customs.

That leads naturally to the question on customs. We have very integrated supply chains. Airbus relies on bits coming from subcontractors, mostly in Europe but not only Europe. We buy from Japan and the US, but predominantly it is a European supply chain. We expect things to move quickly. We ship things from the UK to other sites, and we expect to be able to move them quickly.

A small tariff would probably not be the end of the world. People are more concerned about delays and processing problems. What paperwork is required and what new software systems do we have to install? How many more staff do we have to hire? What training do we have to put them through in order to manage the new system? We are worried more about new bureaucracies and processes than a small tariff. A tariff would not be good, but ultimately it is down to how competitive the UK is. Anything that makes us less competitive will just make the multinationals look at where it is best to do the work. Is it the UK or somewhere else?

Andrew Stroomer: I completely support what Richard says. Specifically on Galileo, in Portsmouth at the moment we have a project team of about 80 people on the ground control segment. Those are the people we are looking to redeploy if we do not have that work coming in on the next phase of the ground control segment.

I have a quick point on timing and the transition period. The important industrial strategy decisions are being taken now. We cannot wait until the end of the transition period, because de facto those positions will have been set and we will not be able to recover them even if we have a very strong agreement at the end of the transition period.

Professor John Zarnecki: The question about customs controls and so on takes me back to the early 1980s when we were in the EU but the single market was not fully operating. I remember the difficulty. We had an instrument on the Giotto spacecraft that flew past Halley's comet. It was built in the UK, it was tested in Germany and the spacecraft was built in France. The difficulty of moving the hardware around Europe and the days spent collecting all the paperwork in the UK and crossing every border were a potential nightmare. That could be replicated for us in the academic and commercial sector.

Philip Davies: The comet was not going to wait for the paperwork.

Professor John Zarnecki: The comet did not wait.

Philip Davies: Nor will many of our investors.

Lord Mawson: It is very much like that today.

Lord German: Does anybody know the number of people employed at the Copernicus data centre?

Richard Peckham: Airbus has a centre in Newport in Wales, but it hosts lots of other data, not just Copernicus. It would be very few jobs; there are probably half a dozen people running the whole data centre, so it would have a minimal jobs impact.

Philip Davies: As regards jobs, a large part of the space industry is multinational. We are part of groups that are present in several European countries, so in a sense they do not need to move work yet, because if it turns out that they need to do so they will move it to another part of the same company. It is generally more straightforward to move work between two parts of the same company than to create a new company.

Lord German: Will people in the same company go to another country? Will they go to France rather than somewhere else?

Stuart Martin: In some cases, yes. If there is a national security involvement, they cannot.

Lord German: Not if they are British.

Stuart Martin: If they are British, they will not be able to move with the work; British security clearance will not qualify them to work on the project.

Q8 **The Chairman:** Can we have a final round-up? I am going to ask each of you if there is anything else you want to say. In addition, if there is one thing you want us to recommend that the Government should do to help the situation, could you record it now?

Dr Lucy Berthoud: Universities UK has produced a briefing paper that outlines policy priorities that the Government should deliver. I recommend that you look at that, because it sets out all the things that could benefit universities on visas, student fees and staff.

The Chairman: I think we have had sight of that.

Dr Lucy Berthoud: Fantastic.

Richard Peckham: There are two things, of which the most urgent is the Galileo situation, because tender decisions are being taken now. Unless we can get the EU and the UK to have a common understanding, we will find that we are moving work out of the UK.

Secondly, I hope that the Government press ahead with the sector deal, because it would put a good flag in the ground that the UK means business and, with or without Brexit, we are going ahead; we have a vibrant industry and we are pretty entrepreneurial. The UK scores very highly entrepreneurially, and, as Stuart said, there are a lot of start-up companies. It is really vibrant at the moment. It is not all about government money; it is about signals and showing that the UK is a good place to do business.

Professor John Remedios: An additional point is that it is not just industrial places such as the Copernicus data centres. We host European organisations such as the European Centre for Medium-Range Weather Forecasts, which also runs Copernicus services. That is quite a serious organisation where we have very close collaboration with the Met Office.

The Chairman: Is that an EU organisation?

Professor John Remedios: No, it is not, but it receives EU money to run services. It is a European public body, so there are definite implications around that.

As regards the Government doing things, it is very important from our sector's point of view that we have a resolved situation around Copernicus, and, if not, a way in which the UK can engage effectively in those international systems. I agree with Richard that a good way of reflecting that would be in a sector deal. I have high confidence that that could do something.

Professor Sir Martin Sweeting: The most pressing problem I face is getting clarity from the EU on the current Galileo situation. The EU currently is insisting on punitive measures, which might range from £3 million to £30 million. If it was at the upper end of that scale, clearly it would destroy our company. We have had strong support from Ministers who have been fighting this. We need to keep up that pressure and get clarity on the EU position.

Lord Mawson: Are they listening? Is there real concern in the Government?

Professor Sir Martin Sweeting: Yes. Jo Johnson was extremely supportive on that in his previous position, but it has yet to be fully resolved and the worst case could be quite catastrophic.

My second point has been mentioned from time to time: the need for a national programme to stimulate and help create the opportunities that have been mentioned and that can be brought on. Associated with that, going back to my point about wider international activities, we need to develop a more pragmatic and approachable export policy.

Stuart Martin: I have two points as well. The first is a further point about the vibrancy of the entrepreneurial part of the sector at the moment. Five years ago, when we started the catapult, there was no venture capital and no private capital coming into early stage businesses at all. Over the last five years, we have helped to set up the world's first venture capital company focusing on space companies, and now I am rung every week by new companies in the UK, the US and elsewhere in Europe saying, "We are hearing about this phenomenon of space in the UK. How can we get involved?" That has completely transformed things. Previously, the only way companies could get started was through government grants; now, increasingly, where there are government grants and we are using them, they are working alongside venture capital

and generating extra leverage in that way. It is proving extremely successful.

The second point is to restate what I said in my opening remarks relating to the national programme idea. What else can government do to help support the entrepreneurial culture and use the environment of Brexit to stimulate new business? There is a genuine opportunity to look at new technologies and how they are going to be used in the development of new policy and regulation and to enforce new regulation, particularly in areas such as fisheries enforcement and agriculture. Those are sectors where we know we need new regulation and new ways of doing things. There is an opportunity to rethink how we use technology in those areas, and space has a real role to play.

Dr Chris Mutlow: For me, it is skills and getting the right people, so we want free movement of people. If we cannot have free movement of people within the European Union, we need to make sure that we have special status in the non-EU countries for bringing in space people, which will help us with the quotas. I fully agree that, if we are to Brexit, we need a vibrant national programme, but we need skilled people to make it happen. I ask that we remember that and that we sort out Copernicus.

Professor Alan Smith: We should stay as close to the ERC as possible and stay in Horizon 2020, and not replace it with a national scheme. That does not contradict my colleague's remark. We should not replace it with a national scheme; somehow we have to stay at the heart of European science.

Professor John Zarnecki: The emphasis of this session has, quite correctly, been on very practical matters and commercial issues, but could I remind us briefly of the inspirational aspect of space? It is very difficult to quantify and to measure, but I am absolutely certain that it plays an enormous part in inspiring youngsters to go into science and technology. There is a danger in the difficult times ahead that, for obvious reasons, we put our emphasis on commercial and industrial matters, and blue skies research drops down the list. A critical part of being a civilised and successful society is that blue skies activities continue to inspire us and, ultimately, produce technical and commercial success, although that is not the prime reason for doing them.

Philip Davies: A statement that we sometimes hear in the press is that nothing is agreed until everything is agreed. That is extremely bad for us. We need agreement as soon as possible, because the longer we do not have agreement, the more irreversible negative things will happen. We need agreements as soon as possible.

I support what Richard said about the sector deal. It is very important for the sector, as is the spaceport initiative, which fills in the one bit of the jigsaw that we do not do in the UK. That could be tremendously stimulating in encouraging people to go into the sector and in giving us end-to-end capabilities. The spaceport initiative is really good, and we hope to hear an announcement quite soon from the Government on that.

Andrew Stroomer: We are in danger of getting to the broken record stage. I reinforce one point, based on what Phil said, which is the criticality of timing. We have talked quite a bit about the defensive and slightly negative connotations in the Galileo and Copernicus sense. It is really important that we get to a sector-level discussion on that.

The other message is the opportunity we have as regards timing at the moment, because the market is changing very quickly. A sector deal is important now to help us to intercept the new regime on space that is coming. We should not all cloud ourselves by negative thinking on Brexit. There is a land of opportunity right here for us as well, and we need to stimulate it.

The Chairman: Thank you all very much. That has been most informative for me and for colleagues. Do any of my colleagues have any final points?

Lord Mawson: I have been communicating with Brian Cox. You will be pleased to know that he agrees with what you are saying. The interesting thing for me as an entrepreneur is that it feels as though this country, over the last decade or so, has seriously got behind your industry and all of this stuff. Take as an example Stephen Hawking's death. It is all amazing stuff, which probably 15 years ago was not there.

It feels to me that there is an amazing opportunity post-Brexit. I agree with what you are saying. How do you bring together the inspirational, practical and entrepreneurial stuff? For me, that is a rich environment, but it requires all of us, including government, to have an honest conversation about what works and what is not working, and which bits of the machinery and mechanics of some of this stuff are not really fit for purpose.

You are in a global industry, and the talent is going to run around the world. It is not just about Europe; it is about America and about how you have a joined-up conversation, because space is of interest to all of us, not just one group. I find what you are saying really exciting, but there is a discipline about how you turn that into a serious, next-stage entrepreneurial venture, which I suspect the country is up for, although I may be wrong. How we help that to happen so that we do not lose the moment, I do not know.

Lord Wigley: Think positive.

Lord Mawson: Indeed.

Baroness Donaghy: I want to make a personal remark, if I may. My father was an aero-engineer at Bristol Siddeley in Coventry. He would have been so thrilled to sit through this session, so thank you very much indeed.

The Chairman: Thank you all. We wish your sector the very best of luck. You may need a bit of luck as well as a bit of help, but clearly you have given us an impression. As you know, we intend to visit Harwell in a

couple of weeks' time. As I said at the beginning, it is not a sector I know much about. I now know a lot more. If there is anything you think we should know, please write to us in respect of either your discussions with government or the Brexit negotiations, but more particularly about what you think Parliament should be urging on our leaders to support your sector. Thank you all very much indeed. It has been most worth while.