Science and Technology Committee

Oral evidence: Satellites and space, HC 804

Tuesday 23 February 2016

Ordered by the House of Commons to be published on 23 February 2016.

Written evidence from witnesses:

- Airbus Group
- Royal Astronomical Society
- Inmarsat
- Surrey Satellite Technology Limited

Watch the meeting

Members present: Nicola Blackwood (Chair); Victoria Borwick; Jim Dowd; Chris Green; Dr Tania Mathias; Carol Monaghan; Graham Stringer; Derek Thomas; Valerie Vaz; Matt Warman

Questions 74-158

Witnesses: **Richard Peckham,** Business Development Director, Airbus Group, **Professor Martin Barstow**, President, Royal Astronomical Society, and **Ruy Pinto**, Group Chief Operations Officer, Inmarsat, gave evidence.

Q74 Chair: I welcome the panel to the second session of our satellites and space inquiry. We are focusing specifically on growth and innovation. We had a fascinating session previously, but we did hear that there are quite a lot of strategies floating around the atmosphere—four at the last count—and a few calls for some extra strategies on Earth observation and other areas. Do you agree with our previous witnesses that these strategies trigger better collaboration among industry, academia and Government, or are they documents sitting on shelves and gathering dust? Professor Barstow, you might like to start.

Professor Barstow: I support the fact that we have the strategies, because for many years we didn't have anything. If you do not have something to work to, to try to plan around, it is very difficult to join things up, so I would support that view. The two I am most familiar with are the innovation and growth strategy and its reboot, and the UK space policy published just before Christmas. They serve different purposes. The innovation and growth strategy is clearly about how we join all the various strands of our endeavour from space research through to the commercial part of space and the downstream sector in a

seamless way. There are lots of tasks we are all now aligned with that are working towards that.

The national space policy is much more top level, very much headline stuff. What is important about it for people like me is that we can wave it about when we go to regional growth funds, local enterprise partnerships and funders and say, "Look, this is what the Government want to happen, and we can make it happen if we work together at regional and local level." They serve different purposes, but all towards the same direction.

Q75 Chair: Do you agree with that, Mr Peckham?

Richard Peckham: I largely agree with that. From an industrialist's point of view, the innovation and growth strategy is the one with which we have had most engagement. Although we use the word "strategy", the latest incarnation of the IGS was the space growth action plan. It was very much a plan of action—a whole series of quite specific actions to be carried out—and it was very much the space community, academia, industry and Government together coming up with a plan of how to grow the sector. I appreciate that the civil space strategy the Government want is about what they need to do to deliver their part of the agenda. From an industry point of view, our main focus is on the space IGS.

Q76 Chair: You do not find that industry and academia are going to Government saying, "We need action in this area," and are being told, "Yes, of course. We'll provide you with a plan."

Richard Peckham: No. At the moment we have quite specific actions and they are being delivered. When we published the initial IGS back in 2010, I think, from memory, 16 actions came out of it. We pretty much ticked off all of them: for example, things like the creation of a space agency and creation of a space leadership council. There were very specific things. When it was time to revamp it, we had done most of what we said. Since our plan was to take us up to 2030, which is quite a long-term perspective, there was no way we were going to get everything back in 2010. We set actions to take us forward at that time, which we have mostly ticked off. Now we have set the next set of actions, which I guess will last for a few more years, and then we will have to revisit it to see what we do next, but at the moment we see these genuinely being carried out by joint groups; we are taking things forward.

Q77 Chair: Mr Pinto, one of the points in the space growth action plan discussed in the previous session was the comment that the greatest challenge now for the space industry is to become more outward looking. Do you think that is true, and how is the space industry doing in achieving or meeting that challenge?

Ruy Pinto: It was certainly true five or six years ago. We were one of those industries that, frankly, loved to talk to one another. We had conferences and we just went round in circles, rather like people saying goodbye at the end of a party, but we are changing that. You can see that today by the satellite applications catapult and the latest industry conference held in Glasgow, I think.

Richard Peckham: Liverpool.

Ruy Pinto: Yes. Glasgow was the previous one. We have attracted players, actors and companies from outside the sector, and that is very important. If we are to deliver on all the strategies and the growth targets we set ourselves, we have to open up and talk to outsiders, and bring in the supermarkets, retail chains, the teaching industry and the airline and training industries. A number of players out there use and can benefit further from space technology. There is realisation that you have to look outside the sector.

Q78 Chair: It was clear from our discussions last week that one of the main barriers to growth at the moment is the skills crisis. This was identified at various points in the different strategies. What progress is being made at the moment, and where do you think the gaps are in the policies that the Government are producing? Mr Pinto, perhaps you might like to start this time.

Ruy Pinto: All of us will have an opinion on that. On behalf of my company and a large part of the sector, I think we have a skills gap. The number of skilled professionals coming into the market is not enough to satisfy either the demand or the growth targets we set for ourselves. There are measures in place, like Tim Peake and the astronaut programme and our engagement with the Mars rover and interplanetary exploration, and they help; they fire the imagination, but that is just one side of the story. The other side of the story is that we have to have what I would call a good, positive feedback circle to generate jobs that are well paid and interesting and will cause more people to go for STEM subjects, studying space and taking an interest in space. We have to kick-start that good feedback circle and keep it going by creating jobs and making the sector interesting and attractive to young people. You can see the completely opposite example in the finance sector where a few years ago an undergraduate or graduate student would think, "I'll go and get rich quickly and work in the finance sector." That is not true nowadays. We have an opportunity. We can provide jobs and interesting things for people to do to develop their careers, and that is complementary to what we have done in terms of firing up the imagination.

Q79 Chair: Mr Peckham, if industry is creating the jobs, but not enough young people are taking up STEM subjects, what more do you think industry can do to bridge that gap?

Richard Peckham: Certainly, we all have to play our part. Speaking just for Airbus, we have an apprenticeship programme; we take on craft and technician apprentices. We have no problem recruiting locally. We get hundreds of applicants for tens of spaces. At graduate level, this year we will be doubling our grad take; we are hoping to take on between 50 and 60 graduates this year, and again we have no problem in attracting really good quality graduates. We are probably lucky because space is seen as quite a sexy subject. People think it is really interesting; they can work on something that will go to Mars, or some such. We are lucky.

At the more experienced level, it can be difficult. If we are looking for very experienced people who specialise in space it can be difficult, as you can imagine, because it is not a big sector; you are looking at a fairly small pool of people. There we recruit from Europe

as well as the UK. Quite a lot of Europeans work in our factories at the more experienced level if we are trying to fill some gaps.

The STEM subjects are not a space problem as such; it is a much broader issue. The country is not producing enough people. I understand it is getting better, but clearly it is a problem. I know from anecdotal evidence that finding good maths teachers for schools is still a challenge. What are we doing to help? Our company has about 60 STEM ambassadors, mostly young people. We encourage our graduates to become STEM ambassadors and, partly in company time and partly in their own time, they engage with schools. I forget the numbers, but several hundred children either come into our factories to have a look round or we visit. We run lessons.

We have recently agreed with our local council to open a STEM centre at our Stevenage plant, particularly taking advantage of the Mars rover work we are doing there. We are developing the Mars rover that will be launched in 2018. It is such an attraction for the kids. We take the prototype rovers to a lot of science fairs. It is something they switch on to and get quite inspired by. To take advantage of that, we are doing this work in the UK. It is being sponsored by the UK Government for the UK to be part of that. You have a more formal STEM centre with proper outreach run by a local college. We are providing the land and infrastructure, and the local college will come and provide it. That is the sort of thing we are doing. We try to engage with science fairs and that sort of thing as much as we can, because space is a great topic for encouraging people into science subjects.

Q80 Jim Dowd: Encouraging STEM particularly for women is a critical issue for us. In the senior management of Airbus—obviously, not the Royal Astronomical Society—and Inmarsat, how many have STEM backgrounds, as a general proportion, or are they accountants, lawyers and former academics?

Richard Peckham: Airbus is an engineering company, so most of the senior managers, other than specialists in HR, finance and so on, tend to be engineers.

Q81 Jim Dowd: Including you.

Richard Peckham: I am an electronic engineer.

Ruy Pinto: Straightaway, I confess to being an engineer. Inmarsat prides itself on being a product technology company; in fact, sometimes we are accused internally of being too engineering oriented. There is a healthy percentage of engineering and STEM background people in senior management, but also in other layers of the organisation. Our commercial people resent that at times.

Professor Barstow: In universities, increasing the number of female scientists is top of the agenda right now. It is poor in engineering and not great in physics, which are two of the key disciplines that feed into the space sector. We are all aware that that needs to be fixed, because it is not good enough right now and we have to do more. The RAS has a very big diversity strategy going on at the moment to try to change that.

Q82 Chris Green: Investment in space is seen as a high-cost and very risky and long-term investment, but our space innovation and growth strategy wants Britain to go from 6.5% to 10% of the world space economy by 2030, and that is reaffirmed by the national space policy. We received evidence that the USA has easier access to finance, especially larger sums, than companies in the UK. What steps can the UK take to put this right? Could we start with Professor Barstow?

Professor Barstow: I was just getting a note from my colleague. Finance is not something we have a lot to do with, so it would be very difficult for me to comment in detail on how important it is. Most of our funding is Government funding, but there is a gap for us. Research grants fund our pure research, but we are very aligned with the idea of translating that research into economic benefit and value. We suffer from not being able to find the right kind of funding, perhaps not in large volumes, and the right opportunities to try to bridge the gap between what we do in research and what goes on outside in the wider world. We were talking about skills. We have been doing quite a lot of work on skills and talking to companies. We got a surprising answer. What we heard back was not that there was a shortage of specific space skills but, in line with your previous report on data, not enough people who understand data and can do programming. That is because the downstream market does not know that it exists yet. They are people who do not see themselves as being in the space business. We need to try to find some support to bridge the gap between academic research specifically around space and the people who will eventually play in that downstream community but we have not yet identified, because they themselves do not know they will be able to benefit from the space sector.

Q83 Chris Green: Is the Royal Astronomical Society doing work to try to bridge that gap by more awareness?

Professor Barstow: What we do in the RAS is more about explaining where the links are. We are in the process of publishing a book on the impact of space, astronomy and geophysics, drawing on evidence from the REF, which gives specific examples of how the research we do has direct downstream impact. A lot of that is the already identifiable stuff. We have not yet as a society done any work in that broader piece, but many of our constituent university departments and the organisations that subscribe to us are working in those areas. If you look around at things like Surrey Satellites and the University of Leicester—you will hear from Strathclyde later today—groups are trying to bridge that gap and are doing a lot of work in that area.

Q84 Chris Green: In terms of finance, Mr Peckham.

Richard Peckham: You put your finger on a good point. It is very hard to compete with the US when it comes to venture capital; there is more in California than in all of Europe. They have tech billionaires who are ready to pump-prime to get it started, and then there seem to be plenty of investors to come in. We have taken a number of steps in the UK to try to improve that situation. One is the Seraphim fund that was recently set up; a specialist space VC fund has now been set up. It was backed by a number of big space companies, including Airbus. We have invested in that fund, but it is being run by a professional VC fund manager, so it will be run properly to look for the right things to

invest in. We are all looking to get some money back from it. That is not why we invested, but clearly it has been done on a business, not a charitable, basis.

Wearing another hat, I co-chair a group called the Satellite Finance Network, which was designed specifically to try to bring in the finance community. It is a network—a way of getting people together. We run conferences and elevated pitch sessions where start-ups can pitch to investors. It is a way of bringing in the investment community. We are making headway. You put your finger on it: a lot of people initially just thought that space was very high risk and would not want to invest in it. As Martin said, it is not all about things up there going to the planets or mining asteroids, which incidentally American VCs are investing in as well. I would say that mining asteroids is a bit of a long-term punt, but a lot of space is very practical—down- to-earth things that can be realised, relatively speaking. It is more about electronics or software than things that go up in space. There are lots of things we can do and are making progress on, but, compared with the US, having entrepreneurs who are ready to take a risk and get in front of investors is still something we need to work on. Training entrepreneurs is something we need to focus on. There is a certain culture and mindset about being ready to take that risk. Clyde Space is a good example of an entrepreneur. Craig Clark literally put his house on the line. He started his company by risking his house.

Q85 Chris Green: If more people appreciated that a great deal of the investment is on the ground and is therefore more secure, more stable and less risky, perhaps you could get more investment in space.

Richard Peckham: That is one of the factors, but even in space it is becoming less risky. To do things in low Earth orbit is no longer high risk. Part of it is about education and part of it is about bringing people together so the finance people meet the entrepreneurs and the start-ups who are going to invest, and vice versa, introducing those people and coaching them. One of the things we have done through the Satellite Finance Network is provide coaching for people who have good ideas. They have something that could become a good business but they are not ready to go and pitch it to investors without a little help, because they all want to talk about their ideas rather than about how the investor will get his money back.

Q86 Chris Green: They are very different skillsets.

Ruy Pinto: I broadly agree with Richard on VC funding and entrepreneurship, the comparisons Richard made and the initiatives like satellite finance. To add to the debate, Inmarsat is a public company, publicly traded. As a mid to big-size company, it has no problem accessing finance. Our issue is not about accessing finance but about doing so on a level playing field at the right cost. Space is seen as a mixed sector, and there are countries that invest a lot of state funds in it, either overtly or covertly. Sometimes for a global company like Inmarsat and, to a certain extent, Airbus in certain cases, it is difficult to compete when, if I am a little more precise, countries like France have export incentives or financing for space companies, not start-ups, that are subsidised. That sometimes distorts behaviour. We try to work with the Government in ensuring a level playing field and I think the Government help us export.

Q87 Chris Green: You have provided written evidence on the difficulties of the lack of export finance availability. If we are looking to see growth by 2030 from 6.5% to 10% of the market, export finance will be critical.

Ruy Pinto: Yes. We should have a more targeted approach to export finance that takes into account competition from other countries, not with the object of subsidising the industry but to make sure that when Inmarsat or companies like Avanti and Airbus are out there exporting they are competing on a level playing field with other countries that do not have the same rules.

Q88 Chris Green: We have to appreciate that for some countries having a presence in space is a bit of a prestige project, and we need to look at what mechanisms we can use to level that playing field.

Ruy Pinto: Absolutely. Broadly speaking, one mechanism is playing to our strengths. All of us talk in various ways about applications, payloads, mobility, safety services and a bunch of markets where the UK has a leading edge, but we need to ensure that when we go out there and sell internationally—Inmarsat makes more than 90% of its revenue outside the UK—we can penetrate those markets and there is a level playing field under whatever rules you apply, whether it be WTO, EU, export credits or whatever it is, so the support of the Government, explicitly and implicitly, is key for us to compete.

Q89 Dr Mathias: Alongside the European Space Agency, do you think the UK needs to have its own national space programme? If so, what are the main reasons for that?

Ruy Pinto: It is a good question. The UK benefits from a national space programme. Having said that, the programme has to be very targeted in emphasising, or being directed to, where we have a leading edge and are competitive. I do not think it is a good use of public funds for the national space programme to bring forward technology that other countries already have. If you want to do that, co-operative mechanisms like the European Space Agency or common programmes in the EU are much more effective, because you team up with other countries and build capability. The national space programme is a very useful one where we can leverage our understanding of our capabilities and where our SMEs and companies are investing, and we can co-invest in R and D. We can help leverage new applications, small companies and so on. Shared programmes like the European Space Agency ones would not have that flexibility. They complement each other.

Richard Peckham: I believe there is scope for a larger national programme. There is already a small programme. There has been a national space technology programme, and a small technology R and D programme exists. There is also a small programme called the international space partnership designed specifically to open up relationships, particularly with developing nations, in space applications. It is about how we can deliver certain practical applications using space. Both of those have been very successful, but there is scope to enlarge the national programme to give more flexibility. In the case of ESA, you are locked into what it does. We have influence. We sit on the councils and can influence what programmes it runs. If there are things that fit with Government policy in terms of

international relations—suppose we want to do something with India—a national programme would give the flexibility to undertake bilateral programmes. You might want to do something with China, India or some of the other developing space nations, or even the US, which you cannot do through ESA. We fully support the emphasis on ESA, as it is today, but a growing national programme to sit alongside it would be very beneficial.

Professor Barstow: I agree with everything that has been said. I would add a slightly different perspective from the point of view of an academic researcher. We are running space science programmes that ultimately produce people who go into industry and technologies that feed into industry. It is also about developing technology capability. We compete very well at the moment, and ESA is very important to us. We win our positions on missions, but we find it increasingly difficult to do so because we are relying on developments put in place decades ago. There is a bit of a disconnect at the moment with investment in the future in order to develop our capabilities so that we can play in that wider arena. We have not been doing that in the past 10 or 15 years to the same extent. There are risks at the moment. I do not think it has become a problem, but a UK-led programme that allows us to do the bilateral things and provides new opportunities, rather than competing with people who already have the capability, is quite important.

At the moment we have a gap—I will not use the cliché "valley of death" in that sense. We have the STFC that funds basic research and the UK Space Agency that funds the building of space missions. The technology bridge between those two in terms of readiness is very hard to get across. We can start some basic research, but then we cannot find any money to translate it into capability that the space agency can then take to ESA. Having a programme that helps get us across that gap will be very important in the future to maintain our competitive edge, both scientifically and eventually commercially.

Q90 Dr Mathias: That is very helpful. Do you have any idea how investing in a UK national programme would compare pound for pound with the European Space Agency?

Professor Barstow: It is always very difficult to ask for more money. I am always hesitant to do that, but it is reasonable to say that at the moment the space programme is a bit overheated. There are more things we want to do than we have resources to do them with. I do not think a national space programme should be on the same scale as what we put into the European Space Agency. In the end, the big impact we are going to have will be through the European Space Agency, by joining together and doing the really challenging things. A small fraction—maybe 10% or 20%—to enable space science on a national scale would make a big difference to what we can do.

Richard Peckham: From recollection, we put a number into the IGS; we talked about a national programme growing to about 50% over a number of years of ESA subscription.

Q91 Dr Mathias: Mr Pinto, what is your opinion?

Ruy Pinto: I agree with the direction of travel, in that co-operative programmes like ESA, in which we participate, should have a bigger slice of funding. The proportion depends on where you are in the cycle. I think we are on the cusp of growth, where if you want to develop applications, the funding is provided in general terms, not only for space

programmes but for other national initiatives like the space applications catapult, which is there to provide an additional return. The direction we should go in is the 50% or so that Richard stated, if we can afford that. If you have to prioritise, you have a choice there.

Q92 Dr Mathias: From a business point of view, are the objectives and missions of the European Space Agency ever in conflict with your company's business plans?

Ruy Pinto: They can be, but one of the advantages we see as a business in the European Space Agency is optionality. Contrary to other international organisations, in the case of the European Space Agency you contribute where you want to, or where your Government put their objectives. To the extent that industry and Government co-operate and collaborate on where they want to invest—applications or the new satellite buses where the UK has an advantage—it makes sense, and we cannot invest in programmes where we do not think there will be a return to the UK. For some of us at least, a typical example is that it does not make sense to invest in launchers. Why put hundreds of millions of euros into a launcher programme when other countries are more than willing to do that and benefit from it? There is conflict, but we have good tools in the European Space Agency construct to contribute to where, quite frankly, we can get a bigger return.

Richard Peckham: ESA has a number of mandatory programmes. Some of it is mandatory. To be a member of ESA you have to contribute to the science, because that was where ESA started. The root was to do space science. When a company like ours responds to an ESA request for a proposal on science we are just a supplier to ESA. If ESA wants to do a science mission that is why it is being done. It is not being done for industrial reasons but because scientists want to go to Mars and find signs of life, or they are trying to detect gravity waves or map the solar system. The objectives are science, and industries like ours are the realisers. We build the spacecraft that will go and get the results. Quite a lot of their science programmes are looking down at the Earth. A lot of what we know about climate change comes from space measurements—measuring ozone, the ice caps, the thickness of the ice, the temperature of the sea and global sea levels. Things like those have very much a scientific purpose. We have developed some very good technology there, which is very much in line with what we would like to do. We are doing R and D to fulfil a science objective and we will develop some good technology along the way.

The other parts of ESA are much more the R and D and supporting the commercial side, which is the sort of thing Ruy was talking about—supporting the commercial sector and trying to level the playing field. As Ruy mentioned earlier, a lot of countries, particularly for defence reasons, put a lot of public money into developing inner space technology. That puts them into a very commanding position in the commercial market, because basically defence budgets have paid most of the development costs. ESA certainly helps us a lot, but it is very responsive to what industry is asking for. It is very much in line with what we are asking for. It realises that when it comes to R and D its role is to help European competitiveness. It takes that seriously and is responsive to where the market is going and what European industry needs to do to remain competitive.

Q93 Dr Mathias: Do you agree with your colleagues?

Professor Barstow: Not running a company, it is a bit hard for me to say. The European Space Agency invests a lot of money, partly ours and partly money from other countries, in infrastructure. We should make sure that we can exploit that infrastructure as much as we can for the benefit of the UK, as everybody else is doing. Earth observation in particular is a key area where we should not miss the opportunities. A vast amount of data flows from there. We need to identify it and let the benefits and expertise flow into the UK.

Q94 Graham Stringer: To follow up that point, do we have enough UK scientists in senior positions in ESA?

Professor Barstow: I would say no.

Q95 Graham Stringer: That was my impression.

Professor Barstow: I think we need more, but we are about to have one. The current head of the UK Space Agency, Dave Parker, is about to take up a post in the human space flight directorate in ESA, but it would be good to have more people and improve some of those links. Having said that, the committees are well populated by UK scientists in terms of things like space policy committees, astronomy working groups and solar system advisory committees. We get in there in quite important ways in shaping policy, and of course we now have the site at Harwell.

Q96 Graham Stringer: But you would say we are light at the very top tiers.

Professor Barstow: I think we are light at the very top.

Q97 Graham Stringer: In terms of the space strategies, do we have the balance right between basic research and commercial research and applications? I am going back to something Professor Barstow said earlier. Is there sufficient pull-through from research into commerce?

Professor Barstow: I do not think so. That is a challenge we all face. It is partly because we have not been pushing that button for long enough to see the real results. If we think of the period since the space and innovation growth strategy was first put together, we are talking of five or six years. Then there was the creation of the catapult, which was one of the mechanisms that we hoped would enable that. It is still slightly early days. We should not lose sight of the fact that we need to keep our focus on making sure that pull-through happens. There is still a lot of work to do. Harwell is an important focus for us, but not all the growth in the regions will happen around Harwell; it has to be in other parts of the country—the midlands, the north and the south-west. There are many individual agencies, for example, regional growth agencies like the LEPs for a start, but also local universities and local partnerships that can draw it through, provided we can channel support. We need some financial support to enable that to happen, because you have to employ people who can do the leg work for you.

Q98 Graham Stringer: That is answering the question about pull-through. What about the balance between basic research and investment in commercial applications?

Professor Barstow: I am not sure about investment in commercial applications. I do not have any particular expertise in that area. Our basic research is good; we have been very successful for many years. While we could invest a little more, it does not have to be a very large amount to fix the current problem of balancing pure research with the application of the research in the space industry. Most of the benefits will be downstream. That is where we should be spending money to get the big wins and the economic benefit and close the virtuous circle that we all think exists, but we have to demonstrate that we can do it.

Q99 Graham Stringer: Mr Peckham, do you have any views?

Richard Peckham: On the pull-through question, from experience working in other non-space sectors over the years, I would say that space does better than most others. Because of the nature of space and space science, we have much closer working relations with universities than, for instance, my colleagues on the Airbus commercial aircraft side would have. There is a natural relationship. Airbus Defence and Space has relationships with probably 20 or so universities in the UK. We are not sponsoring research in all of them, but we are working jointly together on European Space Agency programmes with many of them. We naturally have a close link that supports that pull-through.

On the balance question, I must admit that I probably do not know enough to give a definite answer. In your previous session, the point was made that EPSRC will not fund space research. That is a recurring theme. A number of universities have wanted to partner with us on certain topics. They put in a bid and they keep being turned down. We have often been asked whether we can lobby and go to EPSRC. I have spoken to EPSRC. I think they make a good point. If the bid states that it has an application outside space they are happy to support it, but if it is an application that is only space they think it is too narrow. They probably make a good point, but it is a recurring theme. That is the engineering side rather than the science side of fundamental research, and I think the lack of support from EPSRC is an issue.

Ruy Pinto: From a slightly different angle, it is a difficult question; if you look at basic blue-sky research into space, I would postulate we are at a stage where it would be better to grow the sector and have more short-term investment in commercial initiatives, because that would generate the confidence, the wealth, the tax and the people studying those subjects. Then you could go back and rebalance basic and commercial because you would have a bigger pie to split. I would take that point of view, which is slightly different, understandably so, from Airbus or the Royal Astronomical Society. I am not surprised I am giving that opinion, but there is an argument to be made that more investment in commercial will grow the sector to an extent that makes it easier to facilitate or fund research in the space area.

Q100 Graham Stringer: At the heart of this question is demonstrating impact, isn't it? Mr Peckham, you said in your written evidence that you found it difficult to produce a business case demonstrating an impact for science mission funding. Can you expand on that?

Richard Peckham: I imagine that space is no different from justifying any other science. Payback from science is very long term; it is quite unknown when you embark on the science, and then there can be huge returns. The invention of fibre optics is quoted sometimes. People doing the research thought, "Why are we doing this?" One of the missions we have just done is the LISA Pathfinder mission. Gravity waves have since been discovered on Earth. Anyway, we launched a satellite—the LISA Pathfinder—to detect gravity waves. Lots of people ask me, "What do you want to do that for? What is the payback?" Of course, we do not know, but scientists will tell you that they can think of a lot of ways it might pay back in future just by understanding. It is like a lot of missions. If we find life on Mars, or signs of past life, or whatever, that would be a terrific achievement. Can we financially justify that? I do not know. We recently rendezvoused with a comet. We build quite a lot of that in the UK. It was a 10-year mission to find a comet. I asked Treasury people about that. There was a warm glow in the public; there was a real wow factor, with close-up pictures of the comet. How do you measure that? From the inspiration point of view, you could measure the impact. A lot of people think, "Wow! I could work on something like that." There was definitely a public and media response: "Oh, that's good. We were part of this mission." We developed some good technology. Some of that can sometimes spin off. I would not say that a reason for doing it is that you hope there will be some spin-off technology. The justification has to be its science. You justify that in the same way as any other science, and the other factors are spin-offs and benefits that come from doing science.

Professor Barstow: I hope you realise from what I have said that we are very signed up to delivering impact. When you are applying for space missions, which is my bread and butter all the time, the problem is that you have to demonstrate specific impact from a particular mission, whereas, when we demonstrate impact, it is in a much more global sense over track records of 15, 20 or 25 years. It is very hard to link a specific impact to a specific mission, but in terms of how we benefit the economy globally as space scientists you can point to an awful lot of impact that we have been delivering over a long period of time.

As far as I can see from my interactions with Treasury through the research councils, it gets that part of the argument. That is why it funds science, and it is part of the compact between scientists and funders that we will deliver that. We are not quite sure where it is going to come out in any specific way, because we are trying to look 15 or 20 years ahead. If the impact we are asked to talk about at mission level is allowed to be more global and is demonstrated on track record, showing how we can get to impact, I think it would be helpful.

Q101 Graham Stringer: Talking about impact, another way of looking at investment in science is whether you are going to get value out of the science and value for money. Do you think the money that the United Kingdom has put into the Galileo project has been worth it? We put an awful lot of money into that project, which has had its problems. Do you think it has been worth it?

Professor Barstow: That is a bit outside the space science area. It is probably still not demonstrated yet. On the other hand, looking at the way that kind of global positioning activity will build up over the next decades, it probably will be money well spent. We also

have to make sure we position ourselves to take advantage of the infrastructure we have created. Having independent capability is quite important. If you do not own the capability, somebody can take it away from you. I recognise the security issues surrounding that. Delivering the benefit is a harder ask than putting something in space. It harks back to something I said about pull-through, and identifying where the technology and the products you deliver from an infrastructure like this have an impact in the wider world. We can certainly deliver the impact, but as a country there is a lot of work we would need to do to make sure we benefit from it.

Richard Peckham: Ruy and I spent quite a few years of our lives working on Galileo, so it is quite close to both of our hearts. I was a very strong believer in the programme. For those who remember satellite TV in the early days, it was free to start with and the decoder and encryption came along later—where you had to buy a card to stick in. There were real fears. The US could have done the same for GPS. There is no contract; it is there for anybody to use, and we have become more and more dependent on it. There are some strong reasons why we needed Galileo. Ultimately and interestingly, even the US became very strong supporters of Galileo, because they realised that they were so dependent on GPS that they wanted a back-up. The Chinese have developed something, as have the Russians, but I do not think they wanted to rely too much on either the Chinese or the Russians as back-up.

Q102 Jim Dowd: That is essentially for their cruise missiles.

Richard Peckham: That was how it started, but now it is everywhere in everyday life. Telephone networks go down today. You find the local cell tower has gone because it has lost its timing signal from GPS. Whenever you see that the next bus is due in five minutes, that is GPS. It is everywhere in our lives. When the US realised how dependent they had become on it, suddenly Galileo was for them. We have looked at the numbers. Forgetting all the applications and the other side, in building Galileo the UK contributed about 13.5% of the costs. We have done really well in winning work. Just in industrial return, we won about 20% of the work, so in terms of hard numbers we have got more back in the UK than we spent on it, and that is not even looking at the future, the applications and so on.

Ruy Pinto: As Richard commented, we worked for four years on Galileo. Many of us could make a career out of that. To go back to your question, should the UK have invested in Galileo? Yes. I have no doubt that it will pay off in the long run. Was it money well spent across the years? I would debate that very much. We did not benefit as a company, not because we did not try, but we still maintain the position that having a European navigation capability is an engine for future growth applications and opportunities. It was not money well spent for good and bad reasons. A number of institutions were involved in the programme from the start. One could write a book about how you could have done it differently with hindsight, but I have no doubt that the UK should definitely have been involved in that programme. We as a company did not make any money out of it.

Q103 Chair: I want to ask a narrow question about the issue raised in your written evidence, Professor Barstow, about division of the STP between STFC and NERC, which has apparently created some gaps in funding for specific types of research. You say one researcher has reported that the UK component of the SuperDARN radar network is at risk of

closure and that the creation of a space weather operations centre has been focused only on monitoring outbursts of the sun rather than on space weather more generally. Is this a wider problem?

Professor Barstow: It is an example of some of the gaps that exist. It is not very different from, say, the gap between STFC and the UK Space Agency over technology development. We probably do not want to get into the Nurse report and things like that, but all the research councils have their boundaries. That is inevitable when you have to divide up the areas of play. There is always tension across those boundaries because there is discussion as to whose responsibility it is and who should be spending the money from a tightly constrained and limited budget. It is solvable but it is probably partly an RCUK problem to try to make sure there is communication across those boundaries.

We know that the CSR settlement is relatively benign for science. It is very positive and we would all welcome it. On the other hand, there is always more to do, and more things that we want to spend that money on than we can possibly spend it on. There are bound to be some tensions. It is important to make sure there are conversations that join up required capability, so if we are doing space weather it is a bit silly if we suddenly find we are closing a valuable facility that feeds into space weather. We probably need to think more imaginatively about how that is supported and where it is supported from. It currently sits at a ground-based facility in NERC rather than space-based facilities in the UK Space Agency and STFC. It is a Chinese wall that we ought to be able to break down.

Q104 Carol Monaghan: If I may, I will change the line of questioning a wee bit and look at the potential for a UK spaceport. The space innovation and growth strategy talks about access to space being a barrier to growth and notes that the ability to secure launch sites is decreasing. Mr Peckham, the evidence Airbus gave talked about the lack of a UK launch site not being a barrier to growth. Is that because Airbus is a multinational company, with access to the Ariane programme, for example? Is that specific to your company, or do you feel it is not a barrier to any space company?

Richard Peckham: That was speaking for our company. If I switched hats and put on my trade association hat, it is different. The reason it is not a barrier for our company is that we build bigger satellites. There is not a problem. We book a launch, and there are enough launchers to choose from; it is a competitive market. Often they are our customers. For example, a company like Inmarsat, which might be a customer of ours that buys a satellite, generally manages the launch. They would choose a launch provider. They could choose from three different launch providers.

To switch hats and look at the space and innovation growth strategy, which supported a launch capability, if you are a small satellite provider, and are reliant as a hitchhiker effectively, you cannot book the main launch. If somebody is going to launch a two-tonne satellite and you want to put your 100 kg on it, you are reliant on when that goes; you will be a hitchhiker. If it gets delayed because the programme of the main guy paying for the launch is delayed for some reason, you are stuck. We know that small satellite manufacturers see that as quite an impediment to growth. If they are working with their customers to try to give a guaranteed launch date, they cannot do that, so, yes, it is an impediment to growth for small satellite manufacturers.

Q105 Carol Monaghan: Mr Pinto, a few minutes ago you talked about short-term investment encouraging commercial growth in the area. Do you see a UK spaceport starting to enable new companies to grow around that?

Ruy Pinto: The spaceport discussion has been taken a bit out of proportion. More important than having a spaceport, or not, is having a regulatory regime that incentivises the manufacture of small satellites, which is a growth area—the development and application of CubeSats, microsats and other things—and frees up innovation around launchers. Quite frankly, I think the UK Government should in general take a light touch to what is a growing and innovative segment of the space industry. We have not invested directly in it, but we are looking at it all the time as a larger company, because we think there will be growth coming out of it. From that perspective, making it easier to have a spaceport in the UK is a good thing and we should do it. Making it the nexus or focal point of a policy for access to space is an exaggeration, because the value added of manufacturing small satellites, developing applications and facilitating access to space is important as a whole. That is just one cog in the machine. Let's allow people to build a long runway by the coast, but that will not create the industry.

Q106 Carol Monaghan: We talked about STEM subjects and their take-up across different industries. Don't you feel that having something as visual and central to UK space as a spaceport would start to produce growth and be an inspiration to young people to go into that industry?

Ruy Pinto: I think the jury is out. If you go to Harwell and look at the facilities that RAL has—the space centre, the applications, the lab and so on—I think that is inspirational. A spaceport can be inspirational as well, but I do not think it should be the focus of the policy. It is just one component. If it is well done, it can create a centre. You can have a network effect around it, but I do not think it is the priority. You have the whole supply chain of manufacturing applications and access to space to think about.

Professor Barstow: As an inspirational thing, it could certainly add a component, but it will not dominate, because there are so many other things that play into encouraging people to do STEM subjects. We have Brian Cox, Tim Peake and general space science. It will not transform that landscape particularly, but it will benefit it.

Looking at it from the point of view of somebody who has no particular commercial interest, I would ask whether the business case was strong. If there is a good business case, it will deliver growth around the area where it happens to be located. I would be a bit concerned, having actively flown space missions myself and been at various rocket sites, that the UK's location is a bit problematic. There are a limited number of directions in which you can launch and that restricts your opportunities to put things into orbit. They tend to be polar orbits. There will be restrictions in what you can do from such a launch site and that might affect its commercial viability, but I have not seen the business case so I do not know whether that would have any effect.

Q107 Carol Monaghan: Maybe I could ask you a wee bit more about the launch itself. At the moment, vertical launch has not been included in the plan for a UK spaceport. Do you think vertical launch capabilities would increase the opportunities for space access?

Professor Barstow: You still have to have a trajectory that takes you over other people's land. You cannot launch towards Europe because you are going over populated countries; you cannot launch over Ireland very easily because you are going over a populated country.

Q108 Carol Monaghan: But it depends on where in the UK you choose to put the spaceport.

Professor Barstow: Eventually, launch is not vertical; you have to go on a trajectory that takes you over part of the planet. Whether you are using a space plane, which is one launch solution, or a conventional rocket, the problems are largely the same in terms of where you want to get your payload to in space.

Richard Peckham: Both horizontal and vertical launch are being looked at. Initially, the spaceports were looking at horizontal so it is more the Virgin Galactic type, thinking more about space tourism initially. Even for Virgin Galactic, it is interesting that their business model is changing quite a lot. Whereas space tourism was the reason why they did it, everybody is now looking at satellite launches. Constellation markets are now developing; a lot of small satellites are going up. We won the competition to supply the OneWeb satellite. They are going to be small satellites of 150 kg or so, but there will be about 900 of them. They have already contracted launches for the initial constellation, but you will have to replace these things very frequently. People are now starting to look at a market for something that you can launch as and when you require, which could be either vertical or horizontal. There is now more interest in the UK Space Agency in looking at the vertical launch case as well. There was a recent request for proposals to do studies, and a lot of companies put forward proposals. Our own company has looked at this. Bearing in mind the points Martin made, the only feasible place to launch would be from the very north coast of the country, where there is a nice free bit of sea.

Carol Monaghan: You can see where I am going.

Richard Peckham: You can miss Iceland and you would only go over the top of Greenland before you were high enough. The Russians might start to ask some questions, much as we ask questions about North Korea launching satellites. People might start to make political points out of it; I do not know, but it would be feasible to launch from the north of Scotland. Obviously, with the space plane there are more options, because you just need a long runway and CAA-type regulation. On the point Ruy made, in the existing space industry where all of us have built up a business based on what the UK has funded for many years, if the Government suddenly decided they wanted to divert that money and put it into something completely new where there was no industrial capability, that would make us quite concerned, but I think there is a strong enough commercial case. It has to be done on commercial grounds. If there is a commercial business case for a small launcher, vertical or horizontal, people will come forward. There is a lot of interest being shown in the recent call, and my expectation is that people will come forward with quite innovative and commercial proposals.

Q109 Jim Dowd: Mr Peckham, after a lifetime in this business I am less concerned about whether there is intelligent life out there than whether there is intelligent life on Earth. I want to look at the way the UK Space Agency is attempting to vary third-party liability, which used to be comprehensive. It is now looking at it under a more graduated and discriminatory traffic light system. Is that a good thing, or not?

Richard Peckham: Yes. From an Airbus perspective, it is not something that has caused us a problem. The rules were written on the assumption that satellites were big things and you just launched one of them, and that was it. If you are looking to launch hundreds of small satellites and you have to pay per satellite, you have to have a much more flexible approach that looks at the probability of something falling. If it fell, what is the risk? If it is a tiny CubeSat, it will not do a lot of damage if it lands.

Q110 Jim Dowd: Surely, that depends on where it lands.

Richard Peckham: To some extent, but if it is small it will do a lot less damage. An Inmarsat satellite is 6.5 tonnes. If one of those comes down, it could be quite serious. Yes, we support the proposal. A regulatory working group has been set up on an ongoing basis to look at any regulations that we see as impediments. If we think of something next year or the year after, there is now at least a mechanism where the Government will listen and, hopefully, take a proactive approach to amending regulations.

Ruy Pinto: I understand the concept of traffic lights and trying to make the system more affordable, but let's not over-complicate. Right now we have a regulatory regime that has £60 million, and then we will have three traffic lights and a number of people will make a living out of evaluating whether business case x, y or z is on a green, orange, blue or red traffic light and so on.

Q111 Jim Dowd: I have never seen a blue traffic light.

Ruy Pinto: I am sure somebody in our civil service can come up with that concept. My point is that we should make it easier to launch satellites and further lower the insurance requirements. The UK is in the minority in requiring that, if you look at other countries. We run the risk that, with the laudable aim of making it simpler, we make it even more complicated for a small company to launch a small satellite. That is my plea.

Q112 Jim Dowd: More complicated than the uniform £60 million.

Ruy Pinto: More complicated than a levy. I think that £60 million is too much and it will stifle small satellites. Just lower it. If you look at big companies like Inmarsat and a bunch of others, they already have satellite insurance. There has never been a claim. The established providers that launch big satellites, like Airbus, take all sorts of care so that nothing that could give rise to a claim could happen. The risk is minimal. We are, quite frankly, over-regulating on that front, both for small satellites and for bigger companies.

Q113 Jim Dowd: Mr Pinto, you said in your written evidence that "the role of Ofcom as a domestic regulator does not always marry neatly with UK space policy priorities." We in this building are past masters and mistresses of euphemism. Can you tell us what you mean by that?

Ruy Pinto: I can make an attempt. What we mean by that is that Ofcom as an independent regulator has a set of priorities that does not, if you read the regulations, include fostering economic growth in the UK. Ofcom sometimes will look from a consumer perspective, as it should, and take principled action as a thought leader with other countries. That has been the MO of Ofcom for quite a while. It has been listening to criticism and changing, but it still approaches many of the issues it deals with internationally for space and other industries from too much of a principled approach. I think more joined-up policy among Ofcom, the agency and the industry is a good thing, and there is work to be done. There is now an MOU between the agency and Ofcom that has helped; there is a joint working group. Ofcom has come around and aligned with the industry goals for the UK as a whole, and for the space industry, at the recent World Radiocommunication Conference in November 2015. The outcome was good; I do not debate that, but the way we got there was more difficult than it needed to be. If Ofcom had as part of its remit the objective of working with industry, it would be a good thing.

Q114 Jim Dowd: But how does that differ from the complaints of any operator when confronted with a regulator?

Ruy Pinto: How does it differ in the UK, or across the board?

Jim Dowd: Generally.

Ruy Pinto: In general, what happens is that satellite or space operators look for the best domicile in which to do their business. Satellite operators look at France, Norway or other domiciles and say, "The spectrum regulator, or radio wave regulator, in that country is much friendlier to my industry, so I am going to use them as opposed to using the UK." It would be regrettable if that happened.

Q115 Jim Dowd: You have already covered the point about the satellite spectrum, which I was going to come to, but I was unaware of the extent of the Norwegian space programme.

Ruy Pinto: It is not the Norwegian space programme. I was specifically mentioning that as just one example. From a certain perspective, it is easier to file for an orbital slot and a place in the geostationary arc in Norway than it is in the UK, and international companies will play that. It would be regrettable if we did not have in the UK a regulatory regime that could attract that business, because it is part of our growth strategy.

Richard Peckham: For many years, Ofcom often quoted at us the Act of Parliament under which they were created and which specifically states that they are there to represent the consumer. I agree with what Ruy said, but there has been a definite change of culture. Although that is their remit, when they are on the international stage against France and other countries they bat much more strongly for industry than perhaps five or six years ago. The winds of change are at least in the right direction.

Ruy Pinto: I agree. My point is that there is still work to be done, not only by Ofcom but by both parties.

Q116 Jim Dowd: From what Mr Peckham said, it is obviously an evolution that is producing positive results, even though it may have further to go.

Ruy Pinto: Yes.

Q117 Chair: I have a final question for all of you. We opened this session by talking about all the strategies. There is a very clear goal in the space growth action plan and the space and innovation and growth strategy, which is for us to have 10% of the global space market by 2030, with 100,000 jobs, and an interim goal for us to reach a turnover of £19 billion by 2020. Mr Pinto, do you think we are going to achieve those goals?

Ruy Pinto: We have the capability to achieve those goals. The UK has a competitive advantage in a number of areas, and we have mentioned them throughout the evidence: payloads, small satellites, applications and mobile communications. Inmarsat is a perfect example of a success story. It started as an international organisation. It is a FTSE 100 company. It generates thousands of jobs in the UK, directly and indirectly. If you look at Inmarsat's plans, it is expecting to grow along those lines over the next five to six years. The capability is there, but it is not a slam dunk. It will require a lot of hard work by industry, Government and academia to make it happen. I am afraid it will not happen just by osmosis.

Q118 Chair: Mr Peckham, is there anything you can point to that needs to change in order for us to achieve those goals?

Richard Peckham: I am quite confident that we are on the right trajectory to meet them. When we did the original IGS study in 2009 the data available to us was from 2007. We were then at £6.9 billion. On the latest data from 2013, we are at about £11 billion, so we have nearly doubled in size. The number of jobs was 20,000 then and it is now up to 35,000, so there is already very good evidence we are on track.

The launch debate is quite an interesting one. We want 10% of the world market and we are not in launchers at all. Clearly, that is a bit of the market we are not in, so moving into other areas will help, if there is a commercial business case for it. There will always be more things we can do. The space growth action plan has set objectives for the next few years and we are working through those. Some of it is about regulation. Export is probably the biggest thing we have to achieve. We reckon that at least half of the £40 billion will be export. At the moment it is a good proportion; space is a bigger percentage than other sectors. About 30% of our turnover is export at the moment, but it will probably have to be nearer 50% to achieve that. Export is the biggest challenge.

At the moment, we have various actions. There is a joint strategic working group between Government and industry, so we are doing the right things. I am sure we will identify, as we go through, new barriers or new ways that Government could help, but that will be the biggest challenge. One of the points we made in our written evidence was about how

Government procurement can help. It makes a big difference. If the UK Government act as an anchor tenant, without necessarily buying satellites, and buy services, that puts us in a much stronger position to export those services elsewhere. That is one thing the Government are not really doing today, which they could do. There is enough aggregate demand, and perhaps the Government could find a way of aggregating that demand, but it is tough with lots of different Departments. Earth observation is the classic one. DEFRA, DFID with international disasters and the Department for Transport—loads of people—use data from Earth observation, but at the moment it is very fragmented and the Government have not found a way of aggregating it. They would probably save themselves a lot of money if they could buy once and use everywhere, and it would also help industry by stimulating demand and generating new services.

Professor Barstow: The innovation and growth strategy tells us—I believe it—that most of that growth will be downstream, so what we need to do is capitalise on the expertise we have, which is leading within Europe, and possibly across the world, at developing ideas to do the downstream growth, and find applications for satellite data and the things that come out of the space programme, which currently do not look like space, and make sure we deliver on that. That is what the catapult is for. Making sure the catapult can deliver this, and that it is enabled through its operating hub and spoke network across the UK, will be crucial to achieving that.

Chair: Thank you all for taking the time to come today and answering fully all of the questions we have thrown at you, no matter how naive. If we have any follow-up questions, can we write to you within the timing of the inquiry? Thank you very much for your time.

Witnesses*:* **Patrick Wood,** Group Managing Director, Surrey Satellite Technology Limited, **Ross Marshall**, Head of Operations, Clyde Space, and **Mark Thomas**, Managing Director, Reaction Engines, gave evidence.

Q119 Chair: Welcome to our session on space and satellites. I saw that you were listening closely to the evidence our first panel gave on some of the issues that we are trying to probe at the moment. Perhaps I could start where I finished with the last panel and ask for your assessment of current progress on meeting some of the goals of the IGS and the action plan. Mr Wood, do you think that we are going to achieve those goals? Are we on track for 10% of the global market by 2030?

Patrick Wood: As the members of the last panel said, there is a good opportunity for achieving them. I have been in the space industry a long time. I saw the original case for space and the work on the IGS. If we reflect on where we have come since then, we have made huge strides. Richard Peckham mentioned the change from about £6.5 billion to £11 billion, so we have almost doubled in recent times. We need to keep focusing on where the growth areas are. The growth has always been specified as being downstream, but it is about making sure we have a nice balance of upstream and downstream so that we have the best benefit and the best growth opportunities for the UK.

Q120 Chair: Mr Marshall, do you concur with the views of the previous panel about the barriers that need to be overcome or do you have different views?

Ross Marshall: I broadly agree with what has been said. We have an excellent opportunity. We are already punching above our weight in the space industry. There is an opportunity in a number of sectors where we have the chance to improve. I would be looking for clear actions from that plan. What exactly are we going to do about it? It is all quite high level at the moment.

Q121 Chair: Mr Thomas, two of the specific areas of concern that have been raised with us as a Committee are the skills shortage and exports. Are those things that Reaction Engines battle with, or do you find that they are already under your belt and you are fine?

Mark Thomas: To a degree, yes. We are in a slightly privileged position in that we sit on the boundary of aero and space, developing a next generation propulsion system for future launchers. We draw heavily on the aero part of the aerospace industry. We benefit from that being quite well established in the UK already. We anticipate problems downstream as we get more into the rocketry side of the business—where those skills are going to come from. We have doubled in size in the last year and we are going to double in size again next year. The people we employ today come from established companies in the UK, and they have to be back-filled from somewhere, so we are doing a lot on the outreach side and a lot on the STEM side, for a small company, to try to push people through the pipeline, identify talent earlier in the process and make sure that it is going to be there when we need it. The business we are in is very time critical. We need to be able to move quickly. We need to know that when we turn on the tap the resource is going to be there. Another way we fill that gap is, potentially, through partnerships. If it exists today somewhere in the country, can we partner with an organisation to provide that capability? That is clearly what we did last year with BAE Systems.

Export is very important. We can see a huge market opportunity in the US. We need to be positioned to capture that as well as the funding opportunities. Making sure that we are match-fit and adequately supported to do that is going to be key for our success, and for achieving the targets that have been set, which are pretty ambitious.

Q122 Chair: Yes. One of the issues that Mr Wood raised in his evidence was that, alone among G8 countries, and a number of others, we do not have sovereign surveillance capability. There are a number of applications for that, particularly for Government, and applications for Earth observation data as well as other commercial services. We discussed it a bit in our previous evidence session, trying to understand the cost benefit of the investment level for providing that kind of capability. Could you give us your assessment of whether the investment would be worth it?

Patrick Wood: Certainly. Over the years there has been a lot of investment in eSubmissions that have developed the Copernicus data. That is providing fantastic data. A lot can be done to focus how that data is used. It is very low-resolution data. Often it gives you wide area information around a particular country or region, but when you really start looking for some of those downstream applications, you need higher resolution data that can zoom in on areas and provide more detail and information. From our point of view,

when we look at what other countries have done, they often started with low-resolution imagery and they have developed agriculture and forestry capabilities through their Government, but that has driven a downstream applications market, which has also driven a need a for higher resolution imagery. In most of the export countries that we have delivered imagery spacecraft to, they start with low res and then create a desire for higher and higher resolution imagery, because they are looking for more and more precise answers. That has created growth in many other countries. We see that all around the world in almost every region. It is natural for us to say that that is a great opportunity for the UK. Lots of departments visit us at SSTL with a great need to answer questions, but if there was a co-ordinated approach across Government, a lot of that could be done at a much more economic rate. Space sometimes has the historical tag of being very expensive. Now is the time to assess whether that is really the case, and whether there is a changing economic case for space.

Q123 Chair: Do you share that view, Mr Marshall?

Ross Marshall: Downstream was mentioned by the previous panel—defining what the requirements are for data, and then upstream providing that capability. Whether it is provided as a sovereign capability or bought on the open market, I am not sure. I think we are just scraping the iceberg of the data available from space—that can be provided from space—and that feeds into the whole big-data approach and, as was said previously, the applications that can be spawned off the back of that. I am not an expert on what resolution is required. We should be looking at a system, a network of assets, that can provide different resolutions. In some cases, high resolution, expensive assets are what is required. In other cases, high revisit rates and constellations of loading-solution sensors can give you that data. You have to look at it from a network of assets, not just providing one type.

Q124 Chair: We have to look at it from a more holistic point of view.

Ross Marshall: Yes.

Q125 Chair: Rather as Mr Pinto of Inmarsat was saying. Mr Thomas, if you are looking at the UK picture going forward, to try to achieve the goals that the IGS has set for us—we are looking at sovereign satellite capability and a spaceport—what capabilities do you think we need in order to achieve our goals?

Mark Thomas: I totally get the play to your strengths and invest in the downstream, because that is what is generating value at the moment. There needs to be the balanced approach that Patrick talked about, as well as considering the upstream side of the sector. Obviously, low-cost, reliable, responsive space access is going to be key to achieving the targets. That is accepted, but, as we heard from the previous panel, there are lots of different views on how that can be achieved—sovereign capability in launches, or not. Certainly we are going to be looking at a new generation of launchers. Today, we are still pushing today's technology. There have been advancements and there is a trend towards greater reusability, which is fantastic, because that is going to bring the low cost, but we need to position ourselves to be associated with, if not driving, the next generation of

launchers. That is a personal view. We are well positioned if we can move fast enough. Our own experiences have shown that the ambition and desire are there, but the ability to move quickly enough to seize them often slips us by.

Let me give you a local example. Reaction Engines received a tremendous boost when it was announced that we had achieved £60 million of Government investment back in 2013, but it took two and a half years to get the grant agreement signed, and three years later we still have not seen any of those funds flowing into the company. Potentially, it is a missed opportunity in that it has given our competitors an extra three years to try to find ways to beat our engine. Going forward, we have to be much more dynamic and responsive to seize those opportunities, to be bold and prepared to back some of the transformational and game-changing technologies that you would see if you were in a US environment.

Q126 Carol Monaghan: I am very excited about Skylon, which, for those who have not seen it, looks like a cross between a missile and something from Star Wars. It is quite impressive. You talked about low access to space. I am going to go back to this point again. Does that mean a spaceport in the UK?

Mark Thomas: Skylon is a very exciting proposal, but it is at the top end of reusable space planes. We envisage a multitude of vehicles that could serve the purposes and meet the demands of satellite operators and providers. The economic benefits of a spaceport are just beginning to be understood. For me it is one of those bold-step initiatives. You have to take that step. You have to put the footprints down to really understand what it can do for the UK. A spaceport in the UK feels like a sensible proposition. It feels as though it would be attractive. It would certainly be attractive to smaller and medium-sized enterprises, maybe not the big corporations that are already global and have put down deep roots. Smaller businesses like our own would be very excited about the prospect of having a satellite office, if not main facilities, at a spaceport where we knew that a growing number of aerospace industry players were coming to join the party. The whole model is exciting. It is clearly much more than launching satellites and space tourism; a whole industry could be built on the back of it. In the US that is certainly what we are beginning to see. Do the two things have to go together? Probably not. Next generation launchers and spaceports do not all need to happen in the same place, but it is part of the story of getting to those 2030 targets.

Q127 Carol Monaghan: With the next generation of launchers, do you see a reduction in launch costs as integral to the Skylon idea?

Mark Thomas: Absolutely. It is the fundamental principle. We are aiming for low-cost access to space, but also something that is much more reliable and responsive. Today, the reliability of rockets is not great. There is something like a one-in-20 loss rate. If you can get something closer to an aircraft-type level of operation, which is extremely easy, routine, safe, reliable and low cost, you are on to a winner. Frankly, the world is crying out for something like that, but it will be the next generation of launchers that gets us there.

Q128 Carol Monaghan: When you talk about reduction in costs, have you any idea by how much?

Mark Thomas: Yes. We have targeted an order of magnitude—at least an order of magnitude reduction in the launch costs. For the sake of argument, if it is $150 million to put a satellite into space today, we are down at $15 million. It is significant, but it comes off the back of huge investment in development costs. The ultimate cost of that service is going to be very dependent on how the programme is funded.

Q129 Carol Monaghan: Do the other two panel members feel that a spaceport is necessary or could that investment be better spent elsewhere?

Ross Marshall: It is a very good idea. It will create a lot of jobs in the industry within the country, and it will also attract a lot of foreign investment. As was mentioned previously, it is an attraction for the next generation of graduates and so on. It is a little bit more glamorous than the Harwell campus. It will attract people. It makes the news. A lot of large multinational companies have come to visit us off the back of it, so it will attract a lot of foreign interest. Vertical launch should be what we aim for, certainly in the first instance. It is more achievable. The technology exists. If you aim at technology that does not exist, combined with a business case that does not exist, there is every chance that it will not work.

Patrick Wood: From SSTL's point of view, all the parties that are interested in designing, building and setting up spaceports in the UK have come to visit us. We have been very enthusiastic for them. We are interested in changing the economics of space, so we are interested in very low-cost access to space. If I remember correctly, we have used eight launch sites around the world so far. Some of them are in very remote places, and moving a large amount of equipment to them to do launches is complex. Although that is not the largest cost driver, it is certainly one of the things to consider. If you are sending a team for a month to Plesetsk in a fairly remote part of Russia, it is a complex logistics task. In terms of the economics, we always stress that it has to be low-cost access to space, because the world market for the smaller satellite launcher is very challenging economically, and there are lots of players already producing launchers at a very economic price.

There is also a lot of debate between horizontal and vertical. Both have their positives and negatives in terms of design. Clearly, most of us who build satellites would have to do some redesign on a spacecraft from horizontal to vertical because at some point you have to go through the transition from horizontal to vertical, but I do not think we would see that as a barrier. It is just an extra design step that we would have to go through. It is very encouraging—at the right price point. I keep stressing that it has to be at the right price point, otherwise we will have to go somewhere else. The commercial launching business is a very tough market. I am not sure where you spend $150 million to buy a launcher. I have bought three Ariane 5s in my life. For a 1.5 tonne space launcher, you are probably in the $20 million to $25 million region, so if you are in the 200 kg to 300 kg area, it is a very tough economic business to be in. The UK needs to be aware of what business it is getting into.

Mark Thomas: That is an absolutely valid point. The market is changing rapidly. It is extremely dynamic. If you look at the efforts of SpaceX and Blue Origin, and the attempts at reusability, standardisation and volume production, they are all driving the cost down, so we have to be aware of the fact that it is a moving target. We have to be competitive. Whatever else is proposed has to knock the spots off those other guys in terms of cost competitiveness.

Q130 Carol Monaghan: Is horizontal or vertical an either/or? Could we have both if we have enough space available?

Mark Thomas: Yes. You can do both.

Q131 Carol Monaghan: As long as you get a place that is not terribly highly populated but with lots of area around it.

Mark Thomas: Yes.

Q132 Jim Dowd: Do you have anywhere in mind? The early days of the Atlas rocket started off as a vertical launch and within a few short moments we had a horizontal launch.

Chair: We will try not to repeat that.

Patrick Wood: I would like to make a final comment. The issue is one of recognising where to launch from the UK; the last panel made the comment that most of the low Earth orbit satellites go into sun-synchronous or polar orbits, which is a big determining factor. You have to look in the UK as to where the sensible locations are, with a safety range that will enable that to work. There are locations in the UK that it works for.

Q133 Graham Stringer: Can you tell the Committee what problems and barriers, if any, your companies have in raising cash for R and D?

Mark Thomas: We have been on an interesting journey. I will describe it briefly. Reaction Engines was founded more than 25 years ago, off the back of the invention of an engine for a reusable space plane, the air-breathing rocket engine. It has largely existed through private equity investment. Being very honest with you, people bought into the dream. That was fantastic. They were behind the vision, behind the dream and they invested in the company on a long-term journey. Where we found it more difficult was moving into the realms of Government and industry funding, which is where the programme has to go to be successful. We cannot keep going back cap in hand to private investors. It has to be a collaborative effort—industry collaboration, industry and Government. I guess for us it is new territory for the company. Clearly, lessons have been learned along the way, but the pace feels very different. That is an important point to raise. We need to work on the pace, from the initial decision to receipt of funds, because it is very hard to grow a business with a level of funding uncertainty that can exist for a few years, especially when you are trying to recruit people, put down new facilities and take steps on a development programme. If we could stare at the pace of the decisions and the pace of the funding, as well as some of the demands and the hoops that need to be jumped through by smaller businesses, it would

be helpful. Having said that, Government funding is essential because, when the Government invest, you clearly attract a different sort of investor around the world who takes confidence from that Government investment in the programme.

Q134 Graham Stringer: I am not quite sure I understand you—maybe I do; maybe I don't. Are you saying that the barrier is the evenness of Government funding and research council funding for projects, and that when it is spiky it is more difficult to raise private finance? Is that what you are saying?

Mark Thomas: Yes, a little bit of that. It is phase dependent. There are periods of time, particularly when one is moving from research into development, which is the classic one, where you have to up the pace of the activity and the decision making needs to be a whole lot faster. The funds that are required are larger as well. You have a problem in achieving all those things. There is a need for a balanced portfolio of investments, such as early stage research and near to application, as well as the technology development piece in the middle. There are lots of mechanisms for securing funding. We are only beginning to understand the opportunities that are there. It is the transition from a private investment piece to a more Government investment piece that some companies find difficult, I believe.

Ross Marshall: We seek funding from a few different areas. Locally, it has been from Scottish Enterprise, which has been very helpful, through to European Space Agency projects, which we find very difficult, with the bureaucracy and their attitude towards risk. Although it is R and D, they do not seem to want to take any risks. It does not go hand in hand. It is very difficult for a small business to work with the European Space Agency. With a large bureaucratic organisation you expect long proposal phases, a long time before you see any cash in the first instance and lots of review processes, so it is a process that is very difficult for a small business to cope with. We do some European Space Agency projects. It is good for some things; it is good as a knowledge base, it is good for staff training and it is good for contacts, but it really does not stimulate R and D.

Q135 Graham Stringer: Do you believe it to be the case that start-ups and SMEs are crowded out by the incumbents in the market, particularly the multinationals?

Ross Marshall: For European Space Agency funding, definitely. Although it is supposed to be R and D, they seem to have the attitude that, if it hasn't flown already, you can't fly it. How do you ever break into that market? We do 10% of our business going through that, but we direct our business much more towards the Silicon Valley-type of attitude towards risk. We can accept that, if you are paying less and you want it faster, the probability of success might be lower, but you can do it.

Patrick Wood: Picking up on one of the things that Ross highlighted, one of the challenges, particularly for SMEs and new entrants, is finding flight opportunities. It is a huge barrier to getting into the space industry. It is only after a period of time and a period of heritage that people come to you and are willing to let you fly new technology for the first time. One of the things that we have always been a great supporter of is technology demonstrator programmes that enable small SMEs and small start-ups to fly new technology. Even if it is just a few components or a different type of material that they

want to try, it is incredibly difficult for those types of companies to get those opportunities. When we work with SMEs in those areas, it is always very rewarding, both for our engineers looking at the cutting-edge technology and new ideas, and because we may spin off a commercial opportunity with them to fly it on a commercial mission. It is about how we encourage flight opportunities so that people can get heritage. As Ross from Clyde Space said, people do not believe you unless you have actually flown some of the technology. Some of the new integrated circuits, the FB jets, are all things where people say, "Yes, it's a great idea. It's a great PowerPoint presentation," but that is all it remains until you have actually flown it in space and got the tick in the box that the thing actually works. That is one of the biggest entrant challenges that we have.

Q136 Graham Stringer: Can you explain how the Satellite Finance Network helped your business?

Patrick Wood: From our point of view, we work in the export world. We export somewhere between 95% and 98% of our products. With some developing countries, or developing customers, the access to UK export finance recently has helped tremendously. Any opportunity where we can facilitate deals, where people can get access to other finance, is helpful. We also subscribe to the Seraphim venture capital fund, which Richard Peckham mentioned in the first panel, because we see that as a great opportunity for some of the new entrants and new ideas to get funding. Space is one of the areas where, if you are a new entrant or you have an idea that may not have maturity or is very innovative, people are naturally hesitant. The exception is parts of the world like Silicon Valley, where they are willing to invest in much more innovative and higher risk enterprises. Most of the customers we see want a product that gets into orbit and functions for the life span they want it to, because most of them are basing it on a business model of maybe seven years in low Earth orbit or 15 years in geostationary orbit.

Q137 Chair: We heard very similar comments about the conservatism of the space industry from the satellite applications catapult. They proposed Innovate UK's in-orbit demonstration programme being accelerated for that very purpose so that projects that did not have flight heritage could get access to the market. Is this something you think would be beneficial? Would it address some of the problems that you are identifying, Mr Wood?

Patrick Wood: Absolutely. Both from our own perspective as Surrey Satellite Technology but also for people who come to us with new ideas, we have often pointed them in that direction as well as going to talk to Innovate UK ourselves. It is a perfect opportunity for developing missions that multiple payloads and multiple types of technology can fly on. With one mission you are satisfying many potential users of new technology, and you are giving them the one thing that is really hard in the space industry, which is flight heritage.

Ross Marshall: I totally agree. It is very important to get the opportunity to have something with flight heritage. As was mentioned previously about the data side of things, a lot of the flight heritage is about payloads and things that generate data, as well as some of the flight hardware required to facilitate that. We are very supportive of that. It is important that we get the balance right—where we pitch risk. It is riskier than the standard space mission. We have to assume that they might not all work. The point is that you have not spent a lot of money on it so you can afford to do it again, again and again until it

works. That is certainly the approach they take in the US. They seem to be less demanding of requirements for proof of reliability and robustness, processes and so on. We are not saying you should just launch anything. It is important to get the balance right. Sometimes the pendulum has swung a bit too far in terms of risk averseness.

Q138 Chair: Mr Thomas, do you have experience of this in-orbit demonstration programme?

Mark Thomas: No, not through our company and not personally, but I support the general principle of opportunities for early-stage technology demonstration. The previous panel avoided using the valley of death term, but getting through that TRL barrier, or through the valley of death, is incredibly difficult. I totally support whatever opportunities can be provided to enable companies to demonstrate their technologies and learn by failure and so on in a low-risk environment.

Q139 Jim Dowd: Mr Wood and Mr Marshall, on the point you raised, is the lack of opportunity just a factor of cost, or windows or infrastructure? Is it an opportunity to get stuff literally off the ground?

Patrick Wood: Sometimes you have to work very hard to find launch opportunities. Last year we procured a launcher for a commercial contract to launch three one-metre resolution imaging satellites. We realised we had 100 kg free. We always realised we had 100 kg free on the launch vehicle, and we built an experimental satellite to prove a whole series of technology. It is about looking for those opportunities. Even when we had fitted our own experimental satellite, we helped the University of Surrey Space Centre to fly a CubeSat as well. That launch vehicle actually launched five satellites into orbit.

Q140 Jim Dowd: Do you have these things on the shelf, waiting to take the opportunities when they arise, or do you have to respond very quickly to opportunities?

Patrick Wood: Yes. We have both. We have very good relations with launch companies around the world, because those are the key entry points for us to put our products into space, for them to use the applications. Of course, we are very close with launch companies. We understand the manifests. We also have to understand the complexity of launchers because, as the previous panel said, if you are a small satellite waiting to go on a larger one, you are at the mercy of the larger primes. Then you are bolted to the launch adapter plate, and you can wait an awfully long time. That can be detrimental to the technology that you are trying to fly, or you can miss a time-to-market window. It is harder to do that. Certainly in Surrey Satellite Technology we have people continuously looking for where launch opportunities are, and looking for flexibility, such as whether we can do a deal with a particular country that may own launch facilities and capabilities, or simply looking for a good opportunity for some of the low-cost launchers that have come on the market in previous years, like Dneprs, where all of a sudden there was a release of Russian-made Dnepr launchers on to the market. It is a case of securing them so you can make commercial benefit from them. It is a tough business for a new entrant to understand that market.

Q141 Jim Dowd: I understand that. I asked the previous panel about the effect of the relaxation on the liability requirements. Now of course, the UK Space Agency is also looking at changing—relaxing is probably the wrong word—the licensing requirements. Do any or all of you regard that as a good or bad thing? If it is both, what are the factors?

Patrick Wood: From SSTL's point of view, we know that the UK Space Agency has worked hard to understand the challenges. The regulations and licensing for the Outer Space Act are complex. They have done a lot of work to help industry, and to work with industry to understand the particular challenges. It gets very complicated, whether or not you are a multiple passenger on a launch vehicle, to go through that. You also have the natural hesitancy of launcher companies to launch CubeSats because of their potential lack of integrity. There are solutions where they are put in launch containers. It is really a case of understanding the market and the risks. Of course, all the different launchers have different risk thresholds as well. From my point of view, I have seen a huge amount of work by the UK Space Agency to try to simplify, where they can, but there is still an element of regulatory control that you have to go through. At the end of the day, we are launching into space, so we have to be able to justify that we have done all the work that we would want to do to minimise the risk to the UK Government. Those are the key things. We have been very supportive of the work that the UK Space Agency has been doing.

Ross Marshall: I would agree with that. The UK Space Agency is supportive and is making big steps. As was touched on by the previous panel, they seem to have gone to an intermediate step, with the traffic lights and things, that I do not think is necessary. You can go straight to the end goal. I do not see any need for liability insurance, certainly for small satellites.

Q142 Jim Dowd: Would you say that that is an industry-wide view, from the operators' point of view?

Ross Marshall: Again, it is based on risk. What is the probability? Has a liability case been raised? There has never been one. The probability of two satellites hitting each other, and being able to prove that it was your fault, is infinitesimally small.

Q143 Jim Dowd: Surely, the more there are up there, the narrower that gap becomes. It might be one in a million as opposed to one in half a million.

Ross Marshall: Yes, but it is still infinitesimally small. The insurance industry is saying that it is fine because you can insure it for £60,000, but even trying to build a satellite for half of that, it does not work. It is such a small risk that the UK Government could take that risk on board and manage it as a country. You would then attract a lot of businesses based on that. A company that builds satellites in Glasgow with us regulates them through the US for that reason.

Q144 Jim Dowd: It is like young people trying to insure a car; it is three times the price of the car itself. The CAA wants the same regulating framework for space planes. It wants to

move towards a position where it is the same as for civil aviation. Is that a good idea? Is that sensible?

Mark Thomas: We have been working very closely with the CAA and the Department for Transport, recognising that there is going to be some form of regulation. It would be better to inform that than just be on the receiving end of it. Obviously, as Dr David Parker said, we are talking about high-powered vehicles flying through civilian airspace. They are going to come under CAA rules, effectively. It is going to require a creative approach. You are talking about something that is going to be in airspace for a very short amount of time, so let us not put the entire rulebook on it. They need to be able to abort, they need to be able to return to the airfield and they need certain capabilities. I found a very open and welcoming environment in the CAA and in the Department for Transport. They have been very open to industry's ideas. It is a bit like the previous comment. Listening to industry is important and listening to the operators is important so that we put the right rules in place for the day that that will, hopefully, happen.

Q145 Jim Dowd: In the same vein, is the UK Space Agency's idea of generic analysis of CubeSats beneficial?

Ross Marshall: In relation to CAA regulations?

Q146 Jim Dowd: Yes, the UK Space Agency regulations. Is it irrelevant or do you just not know?

Mark Thomas: It is not my territory, but I would think there would be some form of regulation area.

Q147 Jim Dowd: Basically, they are just looking at the risk across the piece of CubeSats rather than individually.

Mark Thomas: There is a case-by-case logic that could be applied. It depends on the size and location and, therefore, the risk. You take a different approach depending on your perception of the risk for a certain satellite. Again, Dave Parker said that if you are going to put a playing card pack full of satellites into orbit there is probably going to be a higher risk than putting one CubeSat up into a known location by a reliable operator, so maybe there is not a one size fits all for CubeSats.

Patrick Wood: CubeSats are launched in a launch container, so the risk could be minimalised.

Q148 Jim Dowd: But you would not necessarily have to assess each individual.

Patrick Wood: No, but as long as you had assessed that what you were putting inside that box was not going to damage the structural integrity of the vehicle—a bit like putting luggage inside an air-cargo case—it would be something that I would perceive as being feasible. With larger spacecraft, you are carrying a lot more fuel, so I suspect that the risks are more complex.

Q149 Jim Dowd: But they are also easier to assess, given their size.

Patrick Wood: In some ways they are easier to assess, because we do that assessment as part of design proving.

Q150 Jim Dowd: How is the rising demand for space spectrum to be accommodated?

Patrick Wood: It is very encouraging that Ofcom and the UK Space Agency have formed their joint working advisory committee on space spectrum. I sit on that panel and it is very encouraging to see how closely they are now working together. I am not an expert in Ofcom, but I understand that Ofcom has taken the view that they regulate RF spectrum in the UK, or in UK-controlled areas, and not necessarily globally. Since we have had dialogue between the UK Space Agency and Ofcom, I have certainly witnessed in the past year huge understanding from both sides. At the last world regulatory conference, the two organisations went in with a very solid and controlled case. That was the first time I had ever seen that. It is really important for the UK, because things like 5G spectrum will be incredibly important. We see lots of other countries working very hard to capture space-based 5G spectrum. It is good to see that Ofcom and the UK Space Agency are working really closely to do that.

Q151 Jim Dowd: Is it conducive to expansion?

Patrick Wood: Absolutely. It is fundamental to making sure of it, because there is only so much spectrum out there. Of course, we are trying new technologies—optical communication—in the future, so people are moving to different frequencies, but it is still a very congested RF space.

Q152 Chris Green: There is increasing concern about debris in space, and those concerns increase as we get more and more satellites in space, especially the small and tiny satellites that are now going into space. There are concerns that these small satellites are harder to track, and may be less reliable than larger satellites, or certainly the conventional satellites. The UK Space Agency told us that the smallest thing they can track is about the size of a tennis ball. Are these valid concerns, and how are you addressing them?

Ross Marshall: They are definitely valid concerns. Space debris is a very serious and real problem. It is a bit unfair that space debris and CubeSats tend to get associated with each other. There are approximately half a million pieces of debris larger than a marble in Earth's orbit, and a few hundred of them are CubeSats. CubeSats are not the problem. In fact, they may be one of the solutions, because smaller satellites are less likely to collide with each other, and they de-orbit faster.

Q153 Chris Green: Is that because they go into low Earth orbit, decay over time and come out?

Ross Marshall: Yes. They provide a function as well. They are not just debris.

Patrick Wood: Having had many conversations with the UK Space Agency about debris and the licensing of satellites, we are seeing some very positive action by the UK Space Agency to make sure that anything launched from the UK conforms to the 25-year decay international regulation. As Ross said, anything that is launched into very low Earth orbit, less than 300 or 400 km, decays very rapidly. The area of concern is probably in the 500 to 1,000 km orbits, where things can take decades to decay. We are seeing a growing number of spacecraft. It is down to not just the UK but all the nations in space to behave responsibly. It is good to see that the UK Space Agency is taking a lead on that. They are certainly pushing very hard to make sure that we have the right technology in our spacecraft to de-orbit them at the end of their life. That is really important. It is also important as a world that we can track down to, as was said, tennis-ball size at the moment, but we need to be able to track much smaller objects. There are a lot of very small objects. If they collide with a spacecraft, they can cause irreparable damage.

Q154 Chris Green: You spoke about de-orbiting. Am I right in thinking that the satellite itself would have a mechanism, some ability, to project itself into the atmosphere and burn up? Do larger satellites have more capacity to manoeuvre, so if an object is seen they can avoid it?

Patrick Wood: If they are in low Earth orbit, yes, typically the larger ones have a larger fuel load, so they have the ability to manoeuvre. As any object gets close to the orbit of the International Space Station it is advisable to make sure that you pass that altitude as rapidly as possible in a controlled way and in co-ordination with the ISS. The larger spacecraft, like the telecommunication ones that are in geo-orbit, are graveyarded in deep space where they will not decay into the Earth. They will simply stay 300 or 400 km in a graveyard orbit beyond their normal operational orbit. What we are talking about is low Earth orbit, where we have most of the problems with space debris.

Q155 Chris Green: We have seen a substantial increase in the number of satellites, as well as predictions of hundreds or perhaps even thousands in a constellation. Where are we at the moment in terms of our ability to manufacture, and how do you see our capacity to respond to need over the coming years?

Patrick Wood: There is no doubt that we are seeing a lot of interest in constellations and very large constellations. Richard Peckham mentioned OneWeb, which is 900 satellites. Clearly, we have many companies coming to us for studies on several thousand low Earth orbit communication satellites. There is no doubt that over the next five to 10 years we will see an explosion of interest in those types of orbits. The technology is now capable of delivering that. Again, it comes down to whether we can control those orbits. There will be a lot of congestion over the poles, when the spacecraft tend to come together. Can we manage that? Do we need some kind of international control over that in the future, probably in five or 10 years' time? That might be something that definitely needs to be thought about. Even today, companies that are designing these multi-satellite constellations have to think about how they all cross over the poles safely so that they do not endanger each other's spacecraft. We will see a lot more work on that.

Mark Thomas: It is interesting that we have these obvious trends in the industry, the trend towards smaller satellites, constellations and greater reusability of launchers. As we fly forward on the innovation growth strategy, it is very important that we look for the throttles in that—the environmental factors that are going to make that growth more difficult and more challenging. Whether it is early enough investment in launchers or space debris, that is one of the factors that hinders your growth prospects. You need to be working on those areas early enough to make a difference. The volume production is a big challenge, because that is a big shift in the industry, but the companies, especially the two to my left, are fantastic examples of success stories. They have really grabbed hold of that and are making a huge difference; they understood early enough that it was a challenge to be solved, they brought the skillset in to do it and did so very successfully. There are other things out there. We need to go into this with our eyes open and not be complacent that it will just happen by osmosis. It is going to need to be driven and we are going to need to knock down barriers along the way.

Q156 Chris Green: On the skillsets of the new players in space and satellites, with it becoming increasingly cheap—they are incredible figures—to enter the space and satellite industry, is there a risk that there will be more inexperienced players in the market, and concerns that they do not have experience and really understand what you are doing, or is that kind of argument coming from the more established bigger players?

Ross Marshall: It is going to happen whether we want it to or not. A lot of these companies are not from the UK, and they are doing it. What we can provide from the UK is the ability for them to come here and buy products that are of a high quality at low cost. That is where we are trying to position ourselves, with the right balance between cost and quality, getting the tailoring processes in place to give us that. Otherwise they will do it themselves or they will go somewhere else for it.

Q157 Chris Green: The demand is there. Is there a perspective of the established players looking after their territory?

Ross Marshall: Some of the established players are probably a bit concerned. I have seen a big change in opinions over the last few years. Some of the established players were dismissing it a lot at the beginning but now they are starting to get more involved and understanding the situation. There is now an understanding that it is going to happen. We have mentioned a few things such as OneWeb, with Airbus getting involved in that. That is a big change from their point of view. I think they realise that they have to.

Q158 Chair: Thank you very much. That brings us to the end of the session. Thank you for your time. I hope that all of you will let us write to you to follow up on specific points, and let us know progress. There is one particular point. Mr Thomas, you raised the issue earlier about the time lag between the announcement of funding to Reaction Engines and the actual appearance of cash in the bank account. Would you mind writing to the Committee with the details of exactly what happened and the timings? It would be very helpful for the inquiry if we could understand exactly what has gone on and what bureaucratic hurdles you have had to overcome.

Mark Thomas: I will. Thank you.

Chair: I thank all of you for coming before the Committee today. It has been a very helpful evidence session. We hope to publish in the not too distant future.