

Defence Committee

Oral evidence: The Integrated Review—Threats, Capabilities and Concepts, HC 834

Tuesday 29 September 2020

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Members present: Mr Tobias Ellwood (Chair); Stuart Anderson; Sarah Atherton; Richard Drax; Mr Kevan Jones; Mrs Emma Lewell-Buck; John Spellar; Derek Twigg.

Questions 1-51

Witnesses

I: Todd Harrison, Director, Aerospace Security Project, CSIS, Alexandra Stickings, Research Fellow, Space Security and Policy, RUSI, and Dr Bleddyn Bowen, Lecturer in International Relations, Space Policy/Warfare, University of Leicester.

Examination of witnesses

Witnesses: Todd Harrison, Alexandra Stickings and Dr Bleddyn Bowen.

Q1 Chair: Welcome to this Defence Committee hearing on the integrated review, with a particular focus on space-based threats and the risks that the UK is facing, and to identify what defence capabilities, concepts and doctrine are required to respond to them. I am really pleased to welcome three witnesses here today: first, Todd Harrison, director of the Aerospace Security Project at the CSIS, joining us from Washington. Thank you very much indeed, Todd, for your time today. We have Alexandra Stickings, who is the research fellow for space security and policy at RUSI. Thank you to you. Finally, Dr Bleddyn Bowen, lecturer in international relations and space policy/warfare at the University of Leicester. Thank you very much indeed for helping us to try to understand this important area that is part of the integrated review, and for advancing our appreciation of how space and cyber fit into the three traditional services. To start us off, we will want to take a quick overview of where we are, over the last couple of decades. I will ask Stuart Anderson to take us forward, here.

Q2 Stuart Anderson: To follow on from the Chair's point, this has been a fascinating topic to read into, and do the research on, prior to coming on to this Committee. What would be very good, Todd, is if you could set the scene for us and talk of how the space environment has changed in the last 20 years.

Todd Harrison: Over the past 20 years or so, a lot of people have talked about how space has suddenly become a contested war-fighting domain. I would argue that that is not actually true; it was already a contested war-fighting domain and has been almost since the beginning of the space age. After the launch of Sputnik in 1957—the first human-made object put into orbit—it was only two years before we saw the first anti-satellite test, which was conducted by the United States. We launched a missile from a bomber to intercept one of our own satellites in orbit, just to prove that we could do it. Since then, a lot has changed. The threats have evolved in the space domain. Arguably, what has changed in the past 20 years is that we are less assured that we can deter attacks in the space domain.

The four ds have become different in the past 20 years. First, space has become more diverse. We see many more countries and commercial companies using space in a lot of different ways. Secondly, space has become more disruptive. We have seen companies such as SpaceX, Blue Origin and others doing things that used to not be possible. We see a lot of small companies here in the United States and around the world that are launching small satellites that have capabilities that are pretty incredible. These commercial companies are now performing missions that used to be the exclusive domain of Governments, so space has become more disruptive in that sense.

Space has also become more disordered—that is the third d—because our laws, regulations and international agreements have not kept pace with all



the new developments going on in space. For example, we have companies such as Northrop Grumman that are doing on-orbit servicing of satellites in geostationary orbit. How do you license that? How do you regulate it? How do you ensure it is being done in a safe and responsible manner? We are working through those issues now, but that just goes to show that our laws and international agreements were put in place at a time when these types of missions either were not possible or were going to be done only by nation states.

The fourth d is that space has become more dangerous. We see a proliferation of counter-space weapons of all types, mainly from Russia and China. To a lesser extent, we see them being developed and deployed by countries such as Iran and North Korea. Even some non-state actors have been observed using counter-space weapons. There are many different types of counter-space weapons. I would be happy to go into them in more detail, but the ones that concern me the most are those that are non-kinetic: the electronic means of attack; the non-kinetic physical means of attack, such as lasing a satellite; and the cyber forms of attack against space systems. I worry about these because an adversary might perceive that they can get away with it. If it is a reversible form of attack, it might not provoke much of a response—or they still believe it might not. Others might not be aware that the attack has taken place. In some cases, different forms of attacks against our space systems can be difficult to attribute. If you cannot know for sure who is attacking you, it makes it very difficult to formulate a response.

Those are some of the reasons that I think the space domain has really changed and become more diverse, disruptive, disordered and dangerous over the past 20 years.

Q3 Stuart Anderson: Thank you very much, Todd. What you say is very enlightening, and I will pick up one of your points. You said that international agreements and laws have not kept pace with what has been happening, and that it is very fast-moving. Alexandra, I would be interested to know whether in your view the previous security and defence reviews have kept pace with these changes.

Alexandra Stickings: I don't believe they have. I do not think that in previous reviews we have seen space examined to the depth that is actually required. We now see that space is recognised for the important role that it plays, and it is encouraging that it is playing a much larger role in this review. It is moving very quickly; the domain is changing. Todd's overview showed the complexity and the difficulties in understanding it. It is important that within this review we take into context the entire space domain, ranging from the role of space in foreign policy to the defence questions and the role that space plays in national security. It is important to look at that entire environment, the entire ecosystem, of space to ensure that the groundwork is laid now so that in future reviews the right questions will continue to be asked as the environment continues to change.

Stuart Anderson: Thank you.



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- Q4 **Chair:** Dr Bowen, may I ask you to advance here? You may want to come back yourself, but it does seem to me that the politics, or even the politicians, perhaps have not kept up with this. Alexandra talked about the previous reviews taking place. It takes years to develop satellites, yet here we are, pointing up at the sky and saying, "Actually, it's getting very crowded, very busy, up there. There's a little bit of O.K. Corral," and stuff is happening that we are not aware of.

Dr Bleddyn Bowen: Yes. In broad strokes, I agree with what has been said, but I would hint at a note of scepticism about how quick and how new a lot of this is. I give some of my space policy students books from the mid-2000s and they are still pretty relevant in terms of understanding the policy, the politics and the higher legal principles that are being hammered out in these debates about how to manage the space environment; what are the military threats to space systems? What we are seeing is really a maturation of a lot of these technologies and they are being deployed in greater numbers. So, in terms of the contours of the debate, they are not that new.

The reality that space is used for infrastructural purposes is one that has been around for a long time; it is just that it has only been specific experts and niche communities that have understood this. Space has been used for the purposes of war, development and prestige since the dawn of the space age, really. It's just the details of it that have changed. In many ways the military aspects and some of the international political and legal aspects are now, today, picking up where the Soviet Union and the United States left off in the 1980s. In many ways, everything old is sort of new again, so there is a lot to be gained by taking that longer view. For example, some of the initiatives put forward by the Russians today on space arms control go back to 1981. I would push back against the view that everything is new and happening really quickly. It's just that a lot more people are paying attention to it now than previously.

Chair: That is interesting. We will come back to the legislative aspects of what can be done now even though there seems to be a lag. Can we focus a little just on the space industry from a British perspective? John, do you want to take us forward on this?

- Q5 **John Spellar:** Thank you very much, Chairman. This question goes really—before we get into space—to what is happening on the ground in terms of this being built. Where would you say that the British space industry stands in the international rankings?

Todd Harrison: I would say that British companies do seem to have a lot of very advanced capabilities. Surrey Satellite Technology and others in particular are really at the leading edge of building small space systems. I think that British companies are definitely in the mainstream of the new space companies that are pushing the edge of the technological envelope in this current wave of space revitalisation.

- Q6 **John Spellar:** To Alexandra or Bleddyn, what should the Government be doing to support and encourage the development of that industry?



Alexandra Stickings: I would agree with Todd that a lot of UK companies are incredibly well respected; he mentioned the small satellites. I think that, internationally, the UK is seen as a major player in this regard. One of the difficulties has been a lack of a coherent strategy, a lack of a coherent overarching ambition, from the UK Government, which could help to lead. Which particular aspects of the industry, for example, should be promoted? How does the industry fit alongside the MoD's ambitions or other civil ambitions? I think that, if the UK Government can create this overarching strategy, it will lead to industry feeling more confident, perhaps, in how it promotes itself internationally. On the other side, it's about the regulations—for example, through the UK Space Agency—that really determine how different companies might act within the UK and also the situation in terms of foreign investment by other companies coming into the UK.

Q7 **John Spellar:** Bleddyn?

Dr Bleddyn Bowen: I think at present there are around 40,000 workers in the UK space industry, as defined by the UK Space Agency. It is not a small sector, especially by global standards. It is on a par with a lot of other countries in Europe, and with Japan as well. It is very much on the middling tier in terms of space power in the global rankings. It is significant, and it has specific niche strengths in certain areas, such as space sciences across universities—not least, of course, in Leicester. It has a lot of recent development expertise in very specific areas in industry. Small satellites, for example, is an area where the UK has led for a while—well over a decade—although other parts of the world are catching up. The technical specifics elude me, but small satellites would be a particular area that might be of interest, in order to try to sustain a British research and development, and manufacturing, lead in small satellites and commercial off-the-shelf technologies.

It is also worth looking at the larger commercial communications. The UK has companies that are registered here. Inmarsat, one of the world's biggest satellite telecoms companies, is registered in the UK. Continuing to make the UK an attractive place to be a space company would be an area for continued UK support. The IT sector is, again, very important to the UK economy, as is the connected downstream applications economy that comes from the satellite infrastructure that is up there in space as well. The UK may not own a lot of satellites in space or operate a lot of satellites, but the UK economy can create a lot of services and data-based industries that rely on freely available satellite services and data that might be international or owned by other countries or companies in other countries.

Ali is right that we have to be clear about what sectors are deserving of specific, targeted investments more than others, because there is a lot going on across the entire space sector, just in the commercial industrial element. A big part of that would be the UK's wider goals with the European Space Agency, because the story of the British space industry has been one of integration through the European Space Agency. Maintaining a strong, influential role for Britain within the European Space

Agency, and perhaps increasing it, should be a priority for UK space policy for the benefits of UK space science, commerce and industry.

Q8 John Spellar: Where would that leave us with regards to the Galileo programme? Should we in fact be trying to get some sense into the commission, and indeed into the other major players, to get back on to Galileo?

Dr Bleddyn Bowen: The European Space Agency is not part of the European Union, although the European Space Agency acts as the major contractor, and sometimes as the operator, for various EU-funded space projects. Galileo is an EU-funded space project. As I said to the Exiting the EU Committee back in 2018, the EU space industrial policy means that the UK is no longer allowed to bid for the contracts to build large and security-sensitive parts of the Galileo programme. If recent press reports are to be believed, it seems that the UK Government has accepted that and is now looking at other alternatives for other kinds of navigation systems, which may not be a like-for-like replacement of Galileo. The Government is looking at what sorts of systems, if any, might be worth investing in on position, navigation and timing, or PNT. It is that broader question. If we are not doing a like-for-like Galileo replacement, what, if anything, should we be doing?

I look forward to seeing what comes from that, but that is separate from the European Space Agency. However, in the years to come, the UK will have to watch very carefully as to what happens with the new agency for the European Union space programme—the new European space agency that the EU might be developing. That might be one of the new agents for the European Union's 2021 to 2027 space programme. How will that relate to the European Space Agency? There will be interesting years ahead for UK space policy with Europe, broadly defined. But we are very much staying a part of the European Space Agency, and the UK has increased its funding for ESA over the last couple of years. It is not just words; the UK has put more money into ESA since 2018. It is important to maintain that distinction but also realise that what happens in the EU affects ESA as well in various ways.

John Spellar: Thank you very much.

Q9 Mr Jones: Can I just come in on space industrial policy? There seems to be a lack of it. I understand that you have raised concerns about the OneWeb investment. I wonder whether you could just tell us what the implications of that for defence are, and where does it fit into space policy, or lack of space policy?

Dr Bleddyn Bowen: The decision on OneWeb took me by surprise. It was a bit out of the blue when it came in June, if I remember correctly, and it is a big decision. It is a big investment.

Q10 Chair: Sorry, Bleddyn: can you just explain in Noddy language what OneWeb does, and why it is different to the other constellations of satellites? Sorry, Kevan, but I think it needs to be placed into context that it is slightly different.



Dr Bleddyn Bowen: OneWeb is one of these proposed mega constellations of satellites based in low Earth orbit. Just to give you a sense of scale of some of the plans of these mega constellations, at the moment there are over 2,500 satellites, or perhaps 3,000 satellites, in Earth orbit, in its entirety at the moment, currently providing services and data. Some of these mega constellations plan to have tens of thousands of satellites just for their own constellations. They are usually made up of quite small satellites, as opposed to some lorry-sized satellites that other constellations use. So they are thinking about putting tens of thousands of satellites in low Earth orbit and they are usually designed for communications services.

OneWeb is trying to build broadband services from these low Earth orbit satellites. The UK bought a stake in that for, I think, £400 million, over the summer. In terms of defence applications it is interesting that the US Army seems to be perhaps the most interested part of the US federal Government that is interested in the SpaceX equivalent of that—the Starlink system, which is the same kind of idea and business model. There are potential defence communication satellites from this. That might be worth looking into. That is very much for the MoD to decide whether it can provide the communications needs beyond what is already provided by Skynet, and beyond what is already provided by trusted allied partners and also trusted commercial providers already.

There is a potential interest there. In terms of MoD interest it would be worth exploring what the US Army is thinking it can get from the Starlink mega constellation as well, to see if there is a potential UK MoD interest in the OneWeb investment.

Q11 **Chair:** Let us ask our Washington representative, who I think might be able to give us a clue here. Todd.

Todd Harrison: One of the things that the US military has been doing is they have been trying to move to more resilient architectures for space systems—that is, systems that can withstand attack better. Right now, all of our military communications satellites are these big, very expensive satellites that are way out in geostationary orbit, and they are so large, so expensive, we can only afford to buy small numbers of them. So we are critically dependent on each and every one of those satellites. If we lose one, either by accident or deliberate attack, it will take many years to replace, and a lot of money.

What they are looking at is, especially through the Space Development Agency that was stood up in the Pentagon, building what they call proliferated low Earth orbit architectures. That is something equivalent to these mega constellations that private companies are also building. One of the missions they are looking at doing with proliferated LEO constellations is data transport—that is, communications. So OneWeb, Starlink and the Space Development Agency—in many ways they are building similar constellations. They are building these mega constellations in low Earth orbit.



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This is the direction I think that at least parts of the US military want to go, because of the security advantages it gives you. If you lose one, two, a dozen, or 100 of these satellites, you still have a functioning capability. It degrades more gracefully. Also, when you have got a large constellation in low Earth orbit, a user at any point on Earth will likely be able to see and communicate with multiple satellites. If you are blocked in one direction you can communicate through another direction instead. In many ways, it makes you more resilient.

On the UK purchase of OneWeb, I have joked with some of my colleagues in the United States that I am a bit jealous. The UK may end up with a proliferated LEO constellation for data transport sooner than the United States, because you are buying into a company that already has satellites in development and has already launched prototypes in space, whereas we are either exploring the opportunity to use some of the capacity of Starlink—although it will probably take years before they figure that out—or launching our own dedicated constellation of satellites, which will take even longer.

Chair: Thank you for that. Kevan.

Q12 **Mr Jones:** Like a lot of things that this Government do, there does not seem to be much policy behind it. Where does it fit into broader space policy? In terms of the maturity of what is being purchased, where are they at? The MoD seems to be quite cool on OneWeb. What are your thoughts?

Dr Bleddyn Bowen: That is a really good question. The honest answer is that I don't know. In most of these written policies and headline documents, you will not get anything that helps put top-line acquisitions in such context. The last national space policy and national space security policy were released in 2014 and 2015; you will not really get any sense of direction from there on what other key investments, on such a scale, should be made. It is worth pointing out that some of the investments made by the Ministry of Defence in other areas, such as intelligence, surveillance and reconnaissance, or spy satellites more generally, numbered in the few millions or maybe tens of millions, whereas this is on another scale of investment. I can see this fitting into any larger stated policy or ambition, but it will be interesting to see what comes from the integrated review.

The defence aspects of space investments and acquisitions have to come from terrestrial requirements. There is no point having space infrastructure just for the sake of it; it has to meet real terrestrial defence needs. If there is a real terrestrial defence need for this, it would fit into that. It would be more about terrestrial war fighting or the military's priority roles, rather than about a coherent space policy as such—maybe a coherent space defence policy, but not space policy as a whole. With OneWeb's small satellite approach, however, you can see some coherence in the UK's existing strengths in small satellites and the communications technology industry, and with what OneWeb is doing. It will be interesting

to see what the UK gets out of the partnership with the Indian telecoms company which is also now a big stakeholder in OneWeb.

- Q13 **Chair:** Thank you. Alexandra, you have spent a bit of time in the MoD. Have you picked up any gossip about OneWeb in the MoD canteen?

Alexandra Stickings: I haven't picked up any gossip, but I want to follow up on what Bleddyn was talking about. We have seen this Government talking quite a bit about ambition for the UK in space. There is a real ambition to make the UK a very well-respected international space power. One part of that has been about having a sovereign PNT capability, and we saw that with the arguments over Galileo and the potential UK replacement constellation. I believe we are moving in a different direction now. There were interesting discussions around OneWeb and how, as well as communications, this could potentially be repurposed to provide PNT signals from low Earth orbit. How much does the purchase of OneWeb fit into that broader ambition to have sovereign capabilities?

To pick up on the point that Bleddyn was making, this has to come from what is actually required on the ground. What do we need? Also, how can we contribute to allied architectures, and to the systems that we are already part of and that we already use, through our own constellation rather than replicating what is already there? It should be about a system that can augment and is interoperable with GPS and with the signals from Galileo that we may have access to, and that our partners and allies will also have access to, in order to create a broader, resilient structure.

While ambition is good and it is very encouraging to see the ambition from the Government, it all needs to be based in reality and what requirements are there. There may be a question as to how the MoD sees the potential of OneWeb to provide those PNT requirements versus what they already get as users of GPS.

- Q14 **Chair:** Thank you very much indeed. Can I just pick up on the European Space Agency? That was really interesting. Many of us believe that it has been a failure of statecraft that European countries have not been able to reconcile differences to include the UK in the continued Galileo project, bearing in mind the genesis of that was Surrey Satellites. It was a British capability. Here we are now on the outside. The beneficiaries there are probably China and Russia—our adversaries, our competitors—as we now have to establish, as you say, another constellation. Can you help me with what is happening with European politics? You mention the European Space Agency. I would have thought that would have been the sensible place—pan-European and not EU—where Galileo would better sit. However, you seem to hint that there may be an EU space agency developing its own political thoughts here. Did I pick that up correctly, Alexandra?

Alexandra Stickings: Yes. While the European Space Agency is European, it includes some non-European partners. Its focus is much more on the science and the civilian commercial aspects of space. When you start bringing in a programme like Galileo, while there is a civilian signal

from Galileo that will be used by everyone with smartphones and so on, there is also the public regulated service, which is the encrypted military-grade signal from Galileo, intended for use by Government-approved bodies: militaries, blue light services and so on. That sits within an EU security framework, rather than a more science-based framework of ESA. ESA is the project manager. It is because it has the ability to implement programmes, rather than come up with them or manage the security aspects. It all comes down to the UK no longer being a member of the EU and then not technically having access to either the public regulated service or the contracts for the secure parts of Galileo, although we could potentially negotiate access to the PRS.

Q15 **Chair:** Thank you. Dr Bleddyn, do you have thoughts on this?

Dr Bleddyn Bowen: Yes, quite a few. I would disagree that Russia and China would benefit from this and then the UK would have to go after its own strong equivalent programme. As Ali was saying, we can negotiate our access to use the signals of the PRS. UK companies will no longer be able to get the contracts to build future iterations of the programme, but the UK—the MoD—can negotiate access to the services and get the same sort of deal that we have had with the Americans and the GPS for more than 30 years, to just become a trusted user of it. It is worth noting that the Americans and the Norwegians have already signalled their intent to negotiate their access to the PRS as well. If all of NATO otherwise is also using Galileo for the long term—thinking 10 or 15 years from now—it does not make sense for Britain not to be using it.

In terms of the service provided to the users on the ground, if Britain negotiates that access, there is not going to be that much of a difference in actual security and military capabilities. The fallout is mostly on the industrial contracts and keeping that technological skills base on navigation technologies in the UK. That was a really important point for the European Union because its space programmes and space strategies always talk about the principle of EU autonomy and autonomy for EU members, both in terms of industrial strategy and in terms of security and defence. Since the Lisbon treaty in 2009, the EU became a far more active player in security and defence policy and the European Defence Agency—again, a part of the EU—has become far more involved in space as well. Ali is right to say that the EU is taking more of an interest in explicit security applications of space technologies and systems in a way that ESA often does not want to.

ESA is much more civilian, science and commerce orientated, and the EU has taken on more of the military-relevant security and intelligence activities. It will be interesting to see how that relationship is worked out over the next 10 to 15 years, especially as the EU is building something that perhaps looks and sounds more like an EU space agency, as opposed to the European Space Agency.

Q16 **Chair:** That is very helpful, but it still seems bizarre that Britain's most senior, largest military power is excluded from a project that they started in the first place, and that the EU is deliberately wanting to keep us out of



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it. Todd, did you want to come in quickly?

Todd Harrison: When it comes to questions like these—whether it is about PNT or communications—from a security perspective, the sovereignty of the system matters less than the reliability and resilience of the system. Ultimately, the security requirement is to get to a PNT system that is more resilient and more reliable. Whether that is through partnering with Galileo, through building some sort of PNT supplemental system, through OneWeb or through some other technological solution, the end goal should be a more reliable and more resilient PNT capability. The driving factor behind that is the threats that we are seeing. We see extensive GPS jamming from Russia in particular. Whenever we are conducting NATO exercises in the Arctic region, Russia is out there jamming GPS signals over large areas. We see GPS spoofing from Russian forces, and wherever Putin is travelling he has GPS spoofers that are tricking other receivers in that local area. It is a real and present threat. We are seeing these attacks on GPS happen around the world on a daily basis. It is not a matter of sovereignty and of who owns the system; it is a matter of getting an allied system, or a system of systems, that is more robust and that will be able to operate effectively through these forms of attack that we continue to see proliferate around the world.

Chair: Thank you. We have had a great discussion, but we want to move on to the whole issue of threats. Bleddyn, go ahead.

Dr Bleddyn Bowen: Regardless of what the UK decides to do on a sovereign basis with position and navigation technologies, getting that PRS access for the MoD should be a matter of policy priority for the UK—get those negotiations started regardless of what we choose to do on a sovereign basis, because access to Galileo signals is still important for us.

Chair: I am sure that we will do that after we have sorted out Brexit. Richard, do you want to explore a bit further the threats and the changing character of conflict?

Q17 **Richard Drax:** Good afternoon to all three of you. Can I be slightly cheeky? For the next question, which is equally fascinating to me, will you explain in layman's terms, for my own sake and for the sake of all those watching, exactly how you take out a satellite? Bearing in mind that we all rely on them so much, I am assuming that everyone is working on ways of destroying them. I would love to know exactly how countries are planning to do that. Is it by laser, or by bumping one aircraft into another in space? Whatever it is—James Bond-esque or not—I would love to hear in simple layman's terms how that is developing. To my question—I hope the next questioner will forgive me for my interest—are changes in the space domain contributing to a change in the character of warfare, and if so, how? Todd, perhaps you could start off.

Todd Harrison: There are a lot of different ways you can destruct, degrade or destroy space capability. The most common way that people think about is a missile of some sort that you fire from Earth up into space, it strikes a satellite and breaks it into thousands of pieces. We saw that in 2007 with the Chinese ASAT test. We saw it again in 2019 when



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India conducted a test like that, taking down one of their own satellites. That is very overt and very visible, and you are going to produce space debris associated with that no matter how you do it. You could also have one satellite that is already in orbit that can either ram into or fire a projectile at another satellite. Again, you are likely to produce a significant amount of space debris with that. It will be overt; it will be observed by other countries. We will know what happened.

However, there are also a lot of other forms of attack that can disrupt, degrade or even destroy space systems, such as non-kinetic means of physical attack. Here, I am talking about something like a high-powered laser or a high-powered microwave weapon. When directed at a satellite, it could do permanent physical damage. You could overheat parts of the satellite, or you could burn out amplifiers on it and things of that nature, and those are much more difficult to detect. You will see the effect; you may not necessarily know where it came from, and others who are observing this independently—third parties—may not know that anything happened at all.

There are also electronic forms of attack: here, we are talking about jamming and spoofing. These are fully reversible forms of attack, but as long as someone is prohibiting you from being able to communicate with your satellites or receive signals from them, they are as good as dead to you. The challenge, of course, is that these are reversible. You can turn on the jammer and the satellite is no use to you; once the jamming has stopped, then you can resume services. It creates a different escalation calculation for adversaries when they are looking at different forms of attack.

The last form of attack I would mention would be a cyber-attack, and there are many different ways you could do that. Primarily, you would try to get in through a ground station that communicates with the satellite. You could simply try to intercept the data and monitor it. You could also go in and try to corrupt the data that is going through the space system, or in the worst case, you could actually try to get into the command and control link and issue commands to a satellite. We have had documented examples of cyber-intrusions on some US civil satellite programmes—weather satellites—where intruders have actually gotten into the command and control link and had access to issue commands to the satellite. Luckily, they did not do that, and it took several days to scrub the system and make sure the intruders were out of it, but this is a real threat. If you did gain control of a satellite, you could issue commands that would ultimately destroy the satellite and render it useless. There are a lot of different forms of attack, and we see countries like Russia and China making progress in all of these areas.

- Q18 **Richard Drax:** That is very helpful. I think it was my fault for asking that first question, which led you slightly off the question, dare I say it; it was my fault, and I apologise. The question was whether changes in space are leading to a change in the character of warfare, and I would have thought that that question implied, "Does that mean more money is



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going to have to go into space, with less for conventional? Are we going to have a laser that can take out every single tank on the ground in 10 years' time?" and that sort of thing. Is it going to change the character of warfare, and if so, how?

Todd Harrison: I do not know that space and the advancements we are seeing in space are necessarily changing the character of war; I think the character of warfare is changing, and space is part of that. We are seeing many more grey zone types of aggression around the world from Russia and China, where they are taking actions that they believe fall below the threshold of overt conflict. We are seeing that in space, and space is a prime ground for that type of grey zone aggression, with reversible forms of attack, non-destructive forms of attack, and forms of attack where attribution can be difficult. We are seeing that happen more and more.

At the same time, being able to fight in modern warfare is increasingly about being able to see your adversary before they can see you, communicate that information throughout your forces, make decisions faster than your adversary, and prosecute targets faster than your adversary. To do that at greater and greater distances in a more highly contested environment, space is a critical enabler.

Q19 **Richard Drax:** Thank you very much. Alexandra, do you want to add anything to that?

Alexandra Stickings: To pick up on Todd's points on how to take out a satellite, the really important point to pull out of that—

Richard Drax: I am sorry to interrupt you, but that is the next question. This is entirely my fault, but can we stick to the character? As Todd has just said, he sees this as being part of changing the character. What do you think?

Alexandra Stickings: I would agree with Todd that what we see happening in space is a reflection of warfare. People often try to define warfare in space and look at conflict in space as something separate, whereas we should be seeing that it is conflict, it is warfare and it just happens to take place in that environment. We see that sub-threshold, so-called grey zone activity happening in so many different areas, and it is no different in space. To pick up the point about how developments in space are enabling how we fight, it is about how conflict has become much more about precision. Space enables that precision-based warfare rather than what we might have seen previously. It is very important not to not conceive of it separately, but to look at it within a much broader context of conflict.

Q20 **Richard Drax:** Dr Bowen, do you want to say anything on this?

Dr Bleddyn Bowen: A fair amount of my research focuses on those questions, so this is a fantastic question. There is continual change in warfare; warfare always changes in the specific way it is fought. Of course, politics and strategy in the highest levels and the nature of war stay the same, but the way it is actually waged day to day and year to



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year will vary. A lot of these changes have been afoot since the 1980s, when space services were becoming relevant to the battlefield and to tactics and operations, rather than just strategic nuclear warfare.

Ali is absolutely right: it is making warfare more precise. What we see now is Russia, China and some other militaries that may be hostile to NATO doing what NATO has done for the past 30 years, which is effectively to be able to shoot and hit whatever they see. That imposes dispersion on your enemies. What do you do if your enemy has precise munitions? You hide, you disperse, you take out the systems that enable those precision systems, you deny the ability to see or you develop countermeasures, such as more air defences, or precision interception capabilities, such as close-in weapon systems.

On those sorts of things, we are seeing a lot of people picking up where the Red Army left off in the 1980s, responding to the precision airstrike capabilities of the US Air Force in an air-land battle in central Europe in the 1980s. For me, there are changes, but they are longer-term changes; we are not seeing a massive sea change just in 10 years. This is a longer-term evolutionary process, as more people become dependent on space and more militaries learn how to combat and adapt to enemy space capabilities and infrastructure.

Again, it comes back to what kinds of terrestrial warfare you want to wage and how space systems fit into that. Ali was saying that space warfare is part of warfare as a whole. If you are intent on fighting high-intensity warfare, the space systems you want for that will be different from the ones you want if you are only going to be engaging in maritime control operations or light expeditionary warfare against non-technologically advanced adversaries. Terrestrial priorities are still important to understanding how space fits into whatever the modern equivalent of that is.

Richard Drax: Thank you.

- Q21 **Mr Jones:** Clearly, what you are saying is that we have become very dependent on space for modern warfare, and you are right. You have already touched on this in saying that what you need, therefore, is a variety; if one satellite or communication system is taken out, you obviously need a reserve or something else in advance. But what about un-thinking modern warfare? Do we also need to build in strategies for going back to map reading, for example? Your average 20-year-old perhaps could not read a map. Do we need to also look at it from not only a technical point of view, but a training point of view, saying, "If everything goes down, what do you actually do?"?

Dr Bleddyn Bowen: Absolutely. I know the US military does a lot of that in its officer training already, especially in terms of dealing with degraded GPS situations and other forms of navigation that you can rely on in a pinch to get around. Those sorts of things are already being thought about; I don't know the detail as to how far and widespread that is across the MoD, for example, but I know that has been done in various parts of



the US military. The low-tech responses are there, and you can find a lot of ground alternatives. For example, you can develop some navigation aids with ground systems if you are on a defensive footing. If you are doing territorially defensive warfare, you can set up a lot of radio navigation systems on the ground if you know you are fighting a defensive campaign. That is not as useful on an offensive or mobile campaign. There are certain lower-tech, non-space alternatives that might be good enough in a pinch, but maybe not something, like a first-rate capability, that you would want to use if everything was working fine. That adaptation is really important, and it is happening in various militaries.

Todd Harrison: I just want to pick up on that last point. Clearly, wherever possible, you want to have terrestrial alternatives—back-up systems. We are increasingly finding, however, with the evolving character of warfare, that all domains are becoming more highly contested. Bases that used to be sanctuary on the ground are also now under increased threat from longer-range missile forces. In the future we will possibly have to fight without sanctuary, and we will have to fight over much greater ranges. The reality is that a lot of those terrestrial and airborne systems that could be a back-up to space-based systems simply do not have the range to operate in those types of environments, so we are going to be increasingly dependent on space.

What the US military has been doing, particularly in the Space Force—and this is one of the reasons it was created—is focusing more attention on the question, “How do we defend our space systems against attack? How do we design those systems so that they can weather an attack and continue to function, even if at a slightly degraded capacity? Can they continue to function even in the face of attack?”

That is not really new or in itself a change in the character of warfare. Just because an adversary has air defence systems does not mean that we give up on the air domain; we develop capabilities, tactics and ways of operating where we can operate in contested air environments. We are simply having to catch up and do the same thing in space.

Alexandra Stickings: I think that this is where it can be helpful to think not so much about space systems, but rather about space-based assets as part of broader architectures. If you look at communications, they are not just satellites or space systems; they play a role in that broader defence architecture of communications. Alongside that, you will have terrestrial communications. If you look at navigation, yes, space-based PNT is important. You may also have terrestrial systems, and you may also have traditional things such as map-reading or maritime navigation. It is how you put all those together, understanding the benefits that each brings and the risks to each, to create an architecture that is resilient, so that if you lose one part of it, you have that resilience built in.

A much more important part is education within the Armed Services on our dependence on space. It is very easy for everyone to go through their days without necessarily thinking, “How much am I using space all the time through my smartphone, through the internet?” Make sure that the



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Armed Services fully understand all their dependencies and vulnerabilities, to help them work out in which areas they might need some education to ensure that certain skills are not lost if they may be required.

Chair: Thank you. I will pass over to Derek.

- Q22 **Derek Twigg:** I have a question for Todd on capabilities in the future and how they will evolve, particularly kinetic and non-kinetic. One of the key elements of any battle warfare is the element of surprise. How flexible do you think we will be to be able to deal with any future threats?

Todd Harrison: That is a good point. If you look at the physics of it, which is always important in the space domain, because sometimes it is non-intuitive. For example, for launching a direct ascent ASAT missile from the ground to hit a target in low Earth orbit, first you have to wait for the satellite to pass within range of you, and then you fire the missile and, within a few minutes—eight to 10 minutes—you could intercept that satellite and destroy it. If you are trying to hit something that is further out, in geostationary orbit, launching from the ground is going to take you hours before you can hit that object, so you will have much more warning that an attack is in process. You still might not be able to do anything to defend against it, depending on your capabilities on orbit.

What is more concerning are co-orbital ASAT weapons—satellites placed in orbit that either are weapons themselves or that contain weapons. More recently, back in July, we observed that Russia appeared to be testing such a system. Of course, the Soviets had a long history of testing co-orbital ASAT weapons back in the 1970s—they conducted at least 20 tests of these types of systems. An object will be placed in orbit, and we can track it and know that it is there, but we won't necessarily know its capabilities because it is so remote. If the object is in a crossing orbit with your satellite, or if it gradually manoeuvres and catches up with your satellite, it could deploy some other type of weapon, such as firing a projectile, which is what US Space Command believes the Russian satellite did in July, or it could use a non-kinetic means of attack if it got close enough, such as a burst of high-powered microwave energy that could fry the circuits and electronics of the satellite.

Some of these things can happen somewhat by surprise. The space domain is distant, and it can be difficult to track and maintain custody of objects in orbit, depending on where they are and how reflective they are of both sunlight and radar. It can be a very difficult domain in which to keep up with where these objects are and what they are doing.

- Q23 **Derek Twigg:** Could you say a bit more about how we can determine whether a satellite is a weapon or not?

Todd Harrison: It is very difficult, and unfortunately we may not know until the capabilities of the satellite are exercised. One thing you can do if you have an inspector satellite is to manoeuvre it close to an object that is of interest and get a closer picture of it, and from that you may be able to determine some of its capabilities. However, if its means of attack is a high-powered microwave, you are not necessarily going to know that is



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the capability just by observing it up close; you would have to see that capability being exercised and detect the energy coming from it, characterise it, and then determine what it is capable of doing.

When we see things such as the Russians firing a projectile in space, they are deliberately communicating to us that they have that capability. They know that when they test it, we are watching it and observing it and that we are going to know that the capability exists. What I would be more concerned about is countries or particular capabilities where they are not testing it or conducting it in a way that we can observe it.

Q24 Derek Twigg: I suppose the other question that follows on from some comments made earlier is about how the cyber and space domains are interdependent. Could you say a little more about that?

Todd Harrison: Satellites are ultimately dependent on ground stations, both to command them and to receive the data that they generate from space. Those ground stations themselves are a vulnerability for cyber-attacks. The satellites can also potentially be inflicted as well through the whole supply chain of developing, building and testing them. There are many different points at which malicious code could get into them, the components and the sub-systems.

Although the space and cyber domains are very much interdependent, all the other domains are just as interdependent with the cyber domain. Virtually all our modern military systems in all domains have incredible amounts of software in them. They are dependent on communication networks and battle networks that represent various vectors for attack. The cyber-threat that we see is not unique to space; it is across all domains and all types of weapon systems in our forces.

Q25 Derek Twigg: Thank you. Do Alexandra or Bleddyn want to add anything to that?

Alexandra Stickings: I will just follow up on what Todd was saying about being concerned about capabilities that we don't know are there. We see various states testing anti-satellite missiles—Todd mentioned the Russian co-orbital test. We have to ask how much of this is about projecting capability, projecting power and letting us know that they have that, versus whether any of these capabilities would be used in reality—particularly the kinetic attacks, which create debris and have very many unintended consequences in the space environment? If you test an anti-satellite missile, you could inadvertently affect some of your own satellites, so it is about the ones that we can't see.

You do not have to be a major space power to have counter-space capabilities. This isn't just about Russia and China and the great powers. Again, there are questions about whether a full-on conflict in space is in the interests of any of those powers. I am more concerned about the proliferation of these non-kinetic capabilities among the smaller space actors or the non-space actors and how they could affect the space capabilities, again not necessarily just acting in orbit, but affecting ground



systems and stations. Those are much more concerning than the more overt weapons.

Derek Twigg: Bleddyn?

Dr Bleddyn Bowen: I agree absolutely with what has been said by the panel so far. I absolutely agree that it is the electronic warfare or jamming and the cyber or computer network intrusions that are far more likely to happen, because of the consequences of any physical action in space that would require a very large political objective to make it worth destroying various parts of the Earth orbit environment.

If we are looking at the most likely risks, to refer back to James Bond, which was mentioned earlier, it is not "Moonraker", "Goldeneye" or "Die Another Day"; it is more "Tomorrow Never Dies". It is about putting wrong data into critical systems, so spoofing GPS, which is a big plot in the film "Tomorrow Never Dies". It is that more subtle getting into the systems that is far more likely to proliferate.

We know that many different countries—small countries, and even poor countries—have electronic warfare capabilities, and there is no reason why they would not start jamming satellite communications if it was within their capabilities and interests to do so, or start various cyber operations as well. It is not always easy to do, but it is far easier to do some aspects of that than to build a big missile that can hit an object 35,000 kilometres away.

Q26 **Chair:** You mentioned "Moonraker". If memory serves, I think the arch villain was one Drax. I do not know whether there is a link. There is a story there, but the connection between you, Richard, and Ian Fleming is for another day.

We will now move on—we touched on these already—to the non-state actors that we should be concerned about. China has already been mentioned. Their entry on to the stage was quite dramatic back in 2007 when they decided to shoot one of their own satellites down, causing more debris. There was no punishment there, other than condemnation, which shows that there aren't even any rules in place yet. Can you give a quick overview on where you see Russia and China's capabilities, and indeed threats, bearing in mind that this is now the ultimate high ground, and if you dominate space, everything beneath it is yours to control, observe or at least communicate in? Bleddyn first.

Dr Bleddyn Bowen: I am on record as saying that space is not the ultimate high ground. The key arguments in a lot of my work is that if you dominate space, it does not mean that you dominate Earth. Controlling space does not mean that you automatically will control Earth. There are many options for resistance or muddling through, even if you have an adversary that might be able to control space to varying extents. Strategy in warfare is not that simple, despite what many official announcements in recent years say about space dominance. Space dominance is a nice thing to have if you are at war and using space a lot, but it does not guarantee you victory. A lot of things can go wrong. We all know how the wars in

Iraq and Afghanistan have gone for the United States, even though they dominated space. The insurgent forces there never had any space denial capability. There are many ways of working around losing control of space.

- Q27 **Chair:** Sorry, but before we leave that point, which is quite critical, I understand your argument, but let us say that somebody took out all the GPS capabilities in Iraq or Afghanistan. Would that not immediately change our kinetic capability in what we can do on the ground?

Dr Bleddyn Bowen: Yes, the impacts, absolutely—and space is absolutely useful and would make a massive difference—but in terms of the way the high ground is used, to say that you automatically win or lose, in terms of the entire war, is grossly oversimplifying.

- Q28 **Chair:** We wouldn't be able to fire any missiles. Our intelligence picture would change. Ultimately, the removal of space capabilities would have a huge impact. Whether you would win or not is obviously a different matter.

Dr Bleddyn Bowen: If you are able to switch a large variety of systems off completely, all at the same time, yes, but the likelihood of that is another question. You could do it if you used nuclear weapons. That would be quite an easy way to do it, if you were a nuclear weapons state; but then if you are crossing the threshold into the nuclear side, it is another kettle of fish with regard to war planning. So it is not to belittle the impact of space loss, but it is a question of defeat or victory in the war as a whole.

It gets more muddy depending on, for example, how badly GPS is degraded in the Baltic territorial defence scenario it depends. It depends what alternatives you have, how well trained your forces are to adapt, and whether you have a lot more munitions. If your munitions are less accurate, you need to use more of them, so do you have enough ammunition if you are not as efficient with the space forces? It is a grey area, effectively, and it really depends on what space systems are lost and when, and in which scenarios, because it differs a lot in the scenarios.

If you are looking at a Taiwan war scenario, it is different kinds of space dependencies compared to a Baltic defence scenario, for example. Being a bit of an academic, I don't like that term. It may be pedantry, according to some, but for me it is a term that oversimplifies strategic thinking about space, because it really does depend on the nitty-gritty details on which space systems are lost.

In terms of where Russia and China are now, when I was starting my studies in this over 10 years ago, Russia was comfortably, I would say, a No. 2 space power, if we were to try and measure space power. Now I would say that China is very much in a comfortable second place across most indicators of space capabilities and space power. Russia still has a lot of military space capabilities and a lot of heritage to draw on from the Soviet era, as we heard from Todd. The Russians have very specific strengths in space capability, and they have reconstituted or modernised a lot of the military space systems that they had in the '80s, lost in the '90s



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because of economic collapse, and then, in the mid-2000s, started redeploying based on the resurgence of the Russian economy then. But China has developed a massive range of space infrastructure for ubiquitous purposes—war, economic development and prestige.

It is interesting to note how much diplomatic opprobrium China faced after the test in 2007, which created 3,000 pieces of trackable debris in low Earth orbit, versus the somewhat more muted response to the Indian tests last year, which didn't create as much debris but still created a fair amount of debris. I wonder whether we are now at a place where kinetic anti-satellite testing is a bit more normalised.

China has conducted a lot of anti-satellite tests since 2007, with the same kinds of weapons systems, but it has not destroyed a target object in space. Those tests would have been more like flight tests, to make sure they can get a missile to within a particular target zone, as opposed to hitting a target and making a big mess. That Chinese space modernisation, and space power development, is part of that larger economic and technological return of China as a major world power, really; so what China is doing with military space capabilities, for me, is expected of a power of that rank. There is no flattery like imitation and it is copying a lot of what America has done for the past 40 years.

Chair: Thank you. Alexandra.

Alexandra Stickings: I think Bleddyn summed up Russia and China very well there. I think there is a question about narrative, and particularly the narratives we place on the capabilities of Russia and China. You can see that when there is a Russian test or a Chinese test, there is that pushback, I suppose, and calling out the hypocrisy of Russia for testing counter-space capabilities while at the same time pushing for treaties in the UN on preventing an arms race in outer space. Again, we have to look at how we respond to these within the bigger picture of how we are responding to other, non-space activities by Russia and China. It is not just about looking at space separately.

The point Bleddyn made about the Indian test—it was not really glossed over, but we definitely did not see the same amount of condemnation. It was at a much lower altitude, so it was made out to be a responsible ASAT test, because it was trying to minimise the amount of debris. Rather than always calling them out or potentially overreacting to tests, it is more about accepting that these capabilities are here, they will be tested and our adversaries may be developing them.

It is about how we respond to this. How do we ensure that our space systems are resilient and able to withstand any potential attacks? We need to look at it within the security environment and the diplomacy that goes around space. We should consider whether any of these capabilities—I will make the point again—will actually be used in reality. How concerned do we really need to be about certain capabilities, if they are much more about power projection, the question of dominance and the balance of power that we see in orbit?



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- Q29 **Chair:** I have just read a book by Jim Sciutto that you may be familiar with, called "The Shadow War". He speaks about Russia being able to take a satellite that can now orbit a competitor's satellites. Do you agree that that is what Russia is now doing?

Alexandra Stickings: Yes, they are starting to test these capabilities with what we call rendezvous and proximity operations—getting closer to satellites. That is definitely a concern. Todd can probably add a bit more on that.

- Q30 **Chair:** Todd, perhaps you can say in your reply whether the Soviets had a programme whereby they had a series of satellites that they tried to arm with a gun that is normally found under the belly of the MiG-31, in order to be able to shoot other satellites. Is that correct?

Todd Harrison: I believe I have read stories with that account—they tried to use a simple gun in space. More importantly, the Soviets had an extensive programme to develop a counter-space co-orbital satellite weapon, which would crash into another satellite in order to destroy it. That is a capability that the Russians have had for decades. More recently, we have seen that they have been testing satellites, as Alexandra said, that would conduct remote proximity operations. We have seen a projectile being fired; we do not know the exact parameters of that, but it is something that has been observed recently.

In terms of Russian and Chinese posture in space, we have to stop and look at why they are developing these counter-space capabilities. The fundamental reason for conventional conflict is that they want to attack our space systems in order to degrade our power projection capabilities. They saw the capability of US NATO allies during the 1990s, in the first Iraq war and in Bosnia-Kosovo. They saw it in the 2003 Iraq war and the Afghanistan invasion. They saw the tremendous advantage that space gave us to be able to project power around the world—our whole reconnaissance strike complex, as the Russians like to call it, to be able to identify targets and attack them precisely. What they want to do is disrupt that. They want to disrupt those battle networks, so that is why they are building space capabilities that can do that.

That would mean that our forces would have less accuracy in their strikes, which would mean more collateral damage and more casualties on our side, and it would require much greater resources to conduct operations. It is not that they could completely stop us, but they could make it cost us so much more, and make it be so much more painful, that the hope is that they could deter us from involvement just by either attacking our space systems pre-emptively, or by showing that they have the ability to hold them at risk.

Now, in nuclear conflict it is slightly different. In a strategic context, both China and Russia are worried about our increasing missile defence capabilities—perhaps they are overly concerned, given the test record of some of these systems—and they think that our missile defence systems could hold at risk their assured second-strike capability, which is



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fundamental to their deterrence posture. So they are investing in counter-space systems that can defeat our missile defence systems, or at least degrade them. If they can disrupt our missile warning satellites and our nuclear command and control, that gives their second-strike capability greater odds of making it through, and in their minds it restores a more stable nuclear deterrence posture.

We have got to keep in mind that there are the conventional war fighting reasons for them pursuing these capabilities. There are also strategic reasons, and those are inherently tied to missile defence and overall nuclear forces.

- Q31 **Chair:** I think this is what you are alluding to in where the character of conflict is going. It is not direct, kinetic engagement between two states—no one would want that—but you will see interference and economic harm. I understand from both the Russian and Chinese perspectives, their military protocols have changed to include a space element. Is that correct?

Todd Harrison: Yes. Both Russia and China have reorganised elements within their military—Russia multiple times—to elevate and refocus attention on space and space operations. Russia has a space force as part of its aerospace forces—I think it has ended up being somewhat similar to our space force and Air Force. China created the strategic support forces that contain both their cyber and space capabilities, and we have seen them in exercises continue to incorporate space attacks and counter-space weapons into how they plan to operate in future. For example, when they go out in the field to conduct large-scale exercises, we will observe GPS jamming over large areas. That is how they plan to operate in the future, and they are practising that way.

- Q32 **Chair:** We are speaking about state actors. As an analogy, my son and I, on the floor in our house, created out of Lego a beautiful House of Commons Chamber, with the Speaker, all the chairs and all the characters. A non-state actor, in the form of my five-year-old, turned up and ran through the middle of it, knocking everything sideways. I did ask him why he did it and he could not really give an explanation; he just thought it would be fun.

You talked about non-state actors, which concerned me. When we speak about space, we talk about China and Russia, and then Iran and India are involved. On the Kessler effect, how close are we to someone with the mindset of my five-year-old wanting to take us back to the 1950s, which is what would happen if you ended up with a tumble effect of essentially moving out the geostationary orbit because it is just a mesh of debris, as they have been able to send something into orbit to cause that effect to take place? That's a fun one for you.

Todd Harrison: Non-state actors, at least for the foreseeable future, are not likely to have the ability to access launch capabilities to put something directly in orbit themselves. I think the primary forms of attack that are available to non-state actors are electronic and cyber forms of attack. To your point, could they create some sort of space debris event using these



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electronic and cyber forms of attack? The answer is yes. With a cyber-attack, if you could successfully get into the command and control link of a satellite, you would have effectively put a satellite in orbit that you could control. You could do damage to other satellites with that. Whether it would lead to a chain reaction like the Kessler effect, I will leave that to the modelling and simulation folks to determine, but certainly a non-state actor could pose a serious threat on orbit and potentially produce space debris.

Dr Bleddyn Bowen: I agree with what Todd was saying there. There is plenty of evidence of non-state actors engaging in electronic warfare, or jamming by accident or by routine because spectrums just clash, or they override each other. If you have particular radio equipment that is powerful enough, you could engage in jamming capabilities, and then it is a matter of how good your state's electronic warfare countermeasures are and how quickly you can respond, or find out whether this is intentional or not. Electronic warfare would be a big one, potentially for certain very motivated non-state actors.

Another option, of course, would be to attack the ground or ground-based elements of space infrastructure. If you have particularly talented human agents, you could infiltrate control stations or other ground dissemination stations for satellite services, so you can try and look at those entry points as well as cyber-intrusion. There are options, but those, I would think, are more dealable with through standard security and counter-intelligence practices, because those options are open to state actors and their intelligence, special operations or covert operations as well. There are options, but that would just require a certain level of operational security that you would hope would be standard on anything that provides critical national infrastructure or very important military and intelligence capabilities.

Q33 **Chair:** When we visited Corsham last week, where Skynet is operated from, we did ask how vulnerable they would be to some form of attack: for example, if you threw some sort of chemical into the compound and that contaminated it. Yes, there is that vulnerability. Alexandra, do you want to add anything, or shall we move on to focus on UK aspects?

Alexandra Stickings: Very quickly, I agree with what the other panellists have said. The only thing I would add is that in the hypothetical scenario of a non-state actor being able to take over a satellite in orbit, that could be a commercial satellite, and we would not know who that actor was. That is why it is important that there are minimum standards for cyber-security for all space assets, not just military ones. You could theoretically take over any satellite and potentially cause damage with it, so it is just about ensuring that when we are talking about the security of space assets, we are looking at every actor including the commercial sector, not just military or national security satellites.

Chair: So a foreign company could take over a British satellite company and then use those satellites against us. You do not have to reply to that; obviously, I just hope that will never happen.

Let us move on to how the UK military is affected by all this, and where we are going.

- Q34 **Stuart Anderson:** I certainly get the Lego analogy—a normal day in the Anderson household with my kids—but moving back to space, we talked earlier about Iraq and Afghanistan, and the Chair talked about what happens if the satellites are taken out. You have also mentioned China and Russia's concerns with the space capability, but how are UK military operations currently supported in space? Could I ask that to Dr Bleddyn, please?

Dr Bleddyn Bowen: At the moment, by and large, the UK military is highly dependent on the United States for its space backbone and space infrastructure. Skynet is one of the very few sovereign assets that the UK and the MoD have to call upon, and that is five satellites, I think. I am sure Todd or Ali will correct me if I am wrong, but it is around five satellites in geostationary orbit that provide secure communications around the world—minus the Pacific region, for the most part—for the MoD and intelligence users.

Beyond that, we rely on the US equivalents. Those include the US GPS, of course, and the United States' gargantuan spy satellite infrastructure and network of all kinds—visible light spectrum, signals intelligence, and all sorts of other multispectral imagery. We also rely on our European partners: the French and the Germans have their own spy satellite assets, and we receive stuff from them too, so we are plugged into that allied network in terms of the way our space infrastructure is supported, both in Europe and in North America.

We also draw upon the commercial sector a lot, as does the US military. The US military also relies on companies such as Inmarsat and Iridium, for example, to increase its bandwidth if it gets a sudden surge or something like that. We know from both Gulf wars that America and Britain waged, at the start of the war the demand for communications bandwidth far outstripped what the Pentagon could provide, and the commercial sector was able to provide it at fairly short notice. That is generally the mix of where the UK gets most of its space capabilities right now.

The other part where the UK has assets is in space situational awareness, or space domain awareness, as it is now called, which is building a picture of what is going on in space. The Fylingdales radar, even though it is primarily a ballistic missile early warning and warhead tracking radar, can also track some objects in outer space. That feeds into the American space surveillance network and we get that composite data back, which is processed at RAF High Wycombe and then they provide the UK with its own space domain awareness. We have an asset there, but not a whole system on a sovereign basis. France and Germany have their own sensors too so, again, we are part of that allied integration network.

The UK, on a sovereign basis, does not have that much to call upon because we have always had it provided to us by trusted allies. Any future capability investment has to take into account what we really need



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ourselves that may not be provided by allies in a pinch, because those systems have a certain bandwidth. For example, a spy satellite can only do so much every time it passes over a certain territory, and it will be tasked on a national basis. What if the French, Germans and Americans are a bit too busy with their own crises right now and we need our own imagery of a certain area? Is there a bandwidth issue? Is it a new capability that might be useful to our allies? Is it something that will buy us influence with allies? Or is it something more about resilience? Is it about building more Skynets because maybe we just need more sovereign communications bandwidth more than other things? That should be led by a good understanding of terrestrial requirements as well. Space has to meet terrestrial needs. We are coming from a highly integrated history in military and intelligence space.

Q35 Stuart Anderson: Thank you. Todd, is there anything you would like to expand on?

Todd Harrison: One thing I would like to expand on is that many of the US military systems were built from the ground up to be international systems: to have international partners as part of them from the beginning. One I would highlight that has had partnership with the United Kingdom and other allied nations is advanced EHF. That is our most sophisticated generation of communication satellites that are designed to be jam-resistant. We use them for tactical uses, where you would need assured communications, but it is also used for nuclear command and control. From the very beginning of development, the UK was a partner in that system, so the UK has part of the use of its bandwidth and has user terminals; it is part of a whole integrated system.

Many of the United States' military systems are like that. They are international partnerships and that helps us in many ways. First and foremost, it makes operations with our allies easier, because we are more interoperable. If we are using the same systems, it is going to make it easier for us to be able to communicate with one another in the field. Also, it helps pool our resources so we can, as an alliance, apply those resources more effectively to build out our allied space capabilities.

From a deterrence perspective, I think it complicates the calculus a bit for our adversaries. If they want to attack one of these systems, they have to understand that it is not just a US sovereign system. That system is a partnership. It is co-owned by all these other nations and do you really want to be attacking them all? Do you really want to multinationalise that problem by attacking the space system? I think in future we are going to see more and more interest in and opportunities for collaboration with our close allies, such as the United Kingdom, when it comes to building out space systems.

Stuart Anderson: Thank you.

Q36 Mr Jones: May I come on to the Ministry of Defence's space strategy? In 2018 there was a summary of its space defence strategy. Where should it be in terms of the integrated review and what should its priorities be?



May I ask Alexandra to take that one?

Alexandra Stickings: One of the really important questions, which has been partly answered this year, is how we are structuring space capabilities within defence. We have seen previously that it was primarily within the Royal Air Force, partly through RAF Fylingdales and the space operations centre at RAF High Wycombe. That followed a trend where space capabilities are often naturally put within an air force, but it is important that we structure space in such a way that all of defence is able to feed in to the requirements, in particular, because that will determine which space systems we might purchase in the future.

I am encouraged by the appointment of Air Vice Marshal Harvey Smyth as MoD Director Space to provide a focal point for space across defence. It is important to have that voice, not only to provide coherence within the MoD, but to have that one voice from the MoD into Government and into the National Space Council and any other UK ambitions there might be, because many space systems are dual use; they will have civilian and military capabilities.

A lot will be much clearer once we find out a little bit more about what space command will do. Where will that sit? What will its purpose be? What will its remit be in terms of asset control, user requirements, and in how we operate with allies? Picking up on that point, whatever MoD space strategy is developed, it is about how we can create a system that is interoperable with our allies and with other systems, and how our systems in particular add value and resilience to those partnerships. Those are important questions, but it really comes down to how we structure it. If we do not have that structure and that governance of space within defence, it will make all those other decisions much more difficult to implement.

Chair: Thank you, Kevan. Emma, do you want to take us forward on the integrated operating concept?

Q37 **Mrs Lewell-Buck:** My question is for Dr Bowen and Alexandra. In relation to the integrated operating concept, we have heard lots of rhetoric, but we are yet to see any detail or any concrete proposals. Are either of you confident that it will prepare our forces to operate across land, air, sea, cyber and space?

Dr Bleddyn Bowen: These documents are always difficult. In military planning and preparing our forces to fight, they are taught to think creatively for themselves. These documents are not there to tell everyone what specifically to do in every specific situation, because we do not know exactly what situation we are going to be in.

With the existence of the doctrinal documents that have been provided by the MoD, with a lot of input from the RAF for the space doctrines, I think we are in a better conceptual and intellectual position now than we were 10 years ago. The air and space power doctrine has gone through two iterations over the past 10 years, one in 2013 and the current edition in 2017. The 2017 edition is a vast improvement on the 2013 one, and the

2013 one was an improvement on AP 3000, which came before that, if I remember correctly.

In terms of general education, I think they are fine. Whether they are going to prepare them on the ground for actual operations I don't know, because a lot of the time you do not revert to your doctrine when you are actually facing a crisis situation; you rely on your own intuition and what your colleagues are up to. In terms of providing educational materials, I think they are on the right track. There is perhaps room to be more specific about what space is doing for the UK context, but it also reflects the developing perspective of the MoD on space. It has been getting far more into space in its own right over the past five years, especially after the national security space policy first came out in 2014. I hope that answers your question.

Q38 Mrs Lewell-Buck: It does, yes. It seems like we are moving in the right direction.

Dr Bleddyn Bowen: On the whole, yes. There is still stuff that I would want to add into the latest doctrine documents regarding space, but they are definitely improving with time.

Q39 Mrs Lewell-Buck: Alexandra?

Alexandra Stickings: I agree that we are making progress, compared with 10 or 15 years ago, in how space is understood. That said, the understanding of space in terms of what it provides the military and what the vulnerabilities are is very uneven across defence—across the services, but also within them. There is a balance to be had between the use of educational doctrines that provide overviews and what we actually provide service members, in terms of how it affects their jobs. We always have to come down to, do you work in signals, do you work in intelligence, are you on a ship, and how does it affect navigation?

We should look at how we can potentially improve that ongoing education, whether it is through scenarios and war gaming, to allow people to experience a little more in an environment how space affects them. We should give them a much more real-world understanding of how they operate with space and how they might operate without space. We need those high-level documents that give an overarching concept of doctrine, but so much comes down to the practicalities of how space works in military jobs on the ground, whether it is sitting in an office or actually in a conflict. Providing that education will help create a better way of giving that operation across domains.

Q40 Mrs Lewell-Buck: Dr Bowen, did you want to come back in? Then Todd wanted to come back too.

Dr Bleddyn Bowen: Ali just jogged my memory. I still think that one of the best things that the MoD has produced, in terms of documents, is the "UK military space primer" in 2010. In terms of the specifics, it was done really well, so I definitely recommend that document. In terms of specifics, there is a lot to draw from the "UK military space primer" that could be

disseminated more widely and perhaps furnished with more up-to-date examples and illustrations, given that the document is now 10 years old. In terms of the basic technologies and physics, and how things work in space, it is still my go-to document for anyone new to space. I am a bit surprised at how many lower-down MoD officers I engage with have never heard of the document before. The "UK military space primer" is not that well known with the lower ranks. It is well known with the more senior MoD space-centric staff I engage with.

Grasping that sort of document is essential if you want to develop more of a space power culture within the MoD that can understand the geostrategy of space on its own terms, irrespective of their terrestrial blinkers, whichever service they have come from. They are going to approach space thinking, "How does this affect naval warfare, because I am familiar with naval warfare?" They need to approach space from a holistic, terrestrial perspective, and they need to be able to understand what space can offer that other people in the MoD may not understand because they may not be space specialists. That is required reading for my students.

Q41 Mrs Lewell-Buck: Thank you. Todd?

Todd Harrison: I want to pick up something very important that Ali said. Doctrine is not enough; you have to break that down into things that are really tangible for the war fighter. Part of that is incorporating counter-space weapons usage into tabletop war games and then into real-world exercises as well so that folks begin to understand, "Oh, okay, this is how an attack on our space system could happen. These are the effects that we would feel in real life."

With that experience of doing tabletop exercises, real-world exercises, you can start to develop operational concepts: "How are we going to operate in the future in a more contested space environment?" Then, even further from that, you can start to develop actual rules of engagement: "What are the rules of engagement going to be if conflict extends into the space domain? What are we going to consider an armed attack? What will we consider a hostile act? What are proportional responses to these things? How will we mitigate them? How are we going to work around them?"

All that will really stem from putting those counter-space-type scenarios into war games and real-work exercises, and, as we discussed before, since a lot of the UK's space capability is co-joined with the United States, I think those have to be joint exercises, and there has to be a common understanding between allied nations about what the threats are, how we will operate through them and what the rules of engagement are going to be.

Mrs Lewell-Buck: Thank you all. Thanks, Chair.

Q42 Chair: For the millions of viewers who accidentally tuned in but who are now gripped by this fascinating discussion about space, Bledwyn, could you repeat the name of the document that you suggested was important reading?

Dr Bleddyn Bowen: The “UK military space primer”, published by the MoD in 2010.

Q43 **Chair:** Right. I presume it is on eBay or wherever you might be able to find it.

Dr Bleddyn Bowen: Free PDFs on the gov.uk website, last time I checked.

Q44 **Chair:** Fantastic—I can hear everybody clicking now to be able to read it. Can we talk a little about the UK construct? We spoke about the advancement of Russia and China. In 1918, there was a big moment for UK Armed Forces with the creation of the Royal Air Force. This raises the question as to whether the UK should follow suit. I think the French have already gone there; in the United States, Donald Trump created the badge that they wear on their arm, which is rather similar, I think, to “Star Trek”. Should Britain follow suit? Todd, why don’t you give us your thoughts from over there?

Todd Harrison: I confess that, from the beginning of the Space Force/space corps debate in the United States, I felt that it was time for the United States to elevate its space forces to be an independent military service. I note that despite the fact that Trump voiced a lot of support for that, that was at the very end of the process.

This is something that was actually first explored in the United States back in the 1990s, and it was one of the recommendations of the special commission appointed by Congress, which published its findings in 2001. Another commission looked at space reorganisation in 2008. Again, Congress took it up in 2016, and you had a bipartisan coalition in the House of Representatives that passed a Bill that would have created what they called the space corps—an independent military service for space under the Department of the Air Force—back in 2017. That did not pass the Senate, so it did not become law. It was only in 2018 that President Trump weighed into the debate, which did push it across the finish line.

I would say that, for the United States, we are heavily dependent on space; we have very well-developed, significantly sized space forces already. An independent service made sense for us. I do not think that is the case necessarily for other countries. What is important is to elevate the importance of space within organisations and to make sure that it is not co-dependent on the Air Force, because, in reality, space benefits all the military services and forces in all the other domains. It is not uniquely tied to the air. It is an unfortunate accident of history, I think, that many of our space forces were resident within our Air Forces, but it is important to make sure that they have some independence from that. How you structure, and whether it is actually a separate service—a separate branch of the military—is for each country to determine when the conditions are right to do that.

Chair: I am horrified to think that there might be a politician out there taking credit for something that he did not actually do.

Todd Harrison: It is unheard of.

Chair: Alexandra, what are your thoughts?

Alexandra Stickings: I agree. I do not think, at this time, creating a separate service for space would be the right move for the UK. There are a number of reasons for that, partly to do with the very small number of sovereign capabilities that we have at present and the size of the UK as a space power.

The changes that have been made, such as the creation of the director of space role, as well as what we will be seeing coming up with space command, are the right move at the moment. They will allow space to better interact with all aspects of defence, which is incredibly important, and, again, move it out of an Air Force context, while still recognising what are, in some ways, still quite limited capabilities.

There is also a question for the UK in a broader war-fighting context. In a number of areas, we have seen space being called a war-fighting domain. It is interesting that NATO calls it an operational domain. How does the UK intend to move forward, in terms of how it sees those conceptual questions of conflict in space? Would the UK go down a route of creating some kind of offensive space capability, for example? That would change the conversation a bit.

Creating a construct, at the moment, could allow in the future for the creation of a separate service, should we go down that route. But, internationally, the UK is playing the middle ground, particularly its role in the international conversations in the United Nations around arms control and norms of behaviour in space. So I do not think moving in a more overt war-fighting direction, with a separate space force, is the way to go at present.

Q45 **Chair:** Bleddyn, if we did this, would it not be a statement of intent about where we want to go as Global Britain and that we are serious about it? Certainly politically, it would be quite a statement, would it not?

Dr Bleddyn Bowen: Yes, it would, although I am not sure it would get the effects that would you want in terms of space specialists. If you had a space command, the first thing people would ask is, "What are you actually commanding?" There are not a lot of assets for the UK to command, as yet. There is Skynet, some space radar and officers integrated with allied space units, mostly in the United States.

I agree with Ali that the director of space position is very interesting. I hope that brings a more central point of contact and a central voice for space for the MoD as a whole and for US Space Command, and that it helps resolve the division of labour in space, which is currently between the RAF and UK Strategic Command. I am not sure what the logic is in that separation of duties. If the space command helps co-ordinate that better, or congeal it, then space command makes a lot of sense.



I would be sceptical of anything beyond that, because the UK is small in military terms in space, even in terms of personnel. We do not have a lot of personnel who are space specialists, nothing compared to the Americans. It is quite telling that the Chinese, who have a very large military space cadre, do not have a clearly distinct space force. It is still embedded within the larger strategic utilities force. They have the strategic support force.

In my own thinking, writing and research on space power culture, it does not really matter whether you have got an independent force or not. Space will always be treated as a secondary environment to the primary terrestrial forces. Regardless of whether it is independent or not, you need strong space specialist voices within whatever construct you have to say, "This is what space can do for you, based on the requirements you have given us, and here are things we can do that you didn't know could be done because you are not space specialists."

Todd is absolutely right in saying that the Air Force should not have an automatic dominance over space in any military. It is something of an accident of history. The US Air Force has had a strong space cadet culture within it since its earliest days in the 1950s. The Air Force used to have its own crewed space flight programme, and there has always been that battle in the US Air Force: is it doing enough in space? If it does too much, then you might lose space and trigger something more autonomous. That debate has now been resolved somewhat, with the creation of a corps within the Air Force.

For the UK, I agree with Ali that now is not the time. But for the future—this is a question that I really was not asked in the United States at the time—if you are going to build a new service, what problem is it actually solving? That was not clear in the United States debate on it. A lot of people were complaining about the Air Force not doing space acquisitions properly. Other people were going on about space education, the lack of prestige for space roles and careers within the Air Force, and it being treated as, "Nobody goes into space if you want to get to the top of the Air Force"—those military culture attitudes.

So in terms of any movement with the UK organisationally, I hope that the director of space and UK space command help to put space on a more serious footing and maybe help to address those problems. But any significant organisational change has to be clear about what problem it is trying to resolve, and especially for an independent service. But now is not the time for that. We have to see where these new changes are going right now in the UK. We have had loads of changes in the last few years: the National Space Council, which is new; we have got UK Strat Comm itself, which is new; UK space command; and now the director of space. So we will have to see how the current changes play out before we think about any further radical changes. We have to see the next few documents—the new defence space strategy, as well as the integrated review as a whole.

Q46 **Chair:** I think that, in the United States, this was a nice shiny



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announcement, which I am sure President Trump was not going to turn down.

Finally, can I just finally turn to the integrated review? We have an opportunity now to make a mark. I talked about Global Britain. If there was one recommendation in the whole arena that we are talking about here today—Bleddyn, you have written about whether we are a second-tier or a primary-tier space capability—what would you recommend in the integrated review for Britain to excel at, to focus on and to invest funds in? Todd, let's start from your side and what our special relationship would expect.

Todd Harrison: I think that what the United States is looking for from our allies around the world is an increased commitment to defending our space systems—our allied space systems—and making them more resilient, and to better integrating space and defensive counter-space operations into the way that our alliances train together, the way that we fight together and the way that we make decisions together. I think that that is what we are looking for.

In terms of how we organise ourselves, I think it is important that while the United States has a separate service, we just need to make sure that the connections—the military-to-military and civilian-to-civilian connections—across our organisations are clear, and that we know who the four-star equivalent is on each side when they need to talk together. We need to know who the combatant command or equivalents are when they need to talk together, and then at all levels down in those discussions. I think that will be critical going forward.

Alexandra Stickings: You don't have to have a huge number of satellites in orbit to be an important space power; you don't necessarily need to have a huge number of capabilities. There is another part and that is on the diplomatic side. I have mentioned that the UK is playing a much bigger role in international conversations around responsible norms of behaviour through the United Nations. The UK also has the ability to use space for soft power. I think the UK Space Agency has programmes that can work with non-space states for space capabilities that can help with certain problems they might have. It could be monitoring illegal deforestation, for example, or providing information for agricultural purposes, and the UK can play a big role there.

Similarly within the regulatory environment, how space is regulated differs quite vastly internationally, and the UK can again play a role in providing a blueprint for a responsible state that has a decent amount of regulation, so that companies want to work in the UK and want to come to the UK. It can use those projections to say, "Yes, we might not ever be on the scale of the US, in terms of launching and numbers of satellites, but we are very important internationally, because we are able to pull all these strands together and work towards a safe and sustainable space environment in the long term."



Dr Bleddyn Bowen: For key things for the integrated review, I would say that there are particular areas that are definitely worth exploring further, and potentially for investments in capabilities, based on existing research and development or gaps in capabilities, in terms of communications, space situational awareness or space domain awareness, and intelligence, surveillance and reconnaissance. Those are not in any particular order, but they are the three capability sectors that I think might be most useful for the MoD if we are to have any large, more significant, further investment in space. The UK MoD and DSTL already have projects on space surveillance and intelligence from space, so seeing how they can fit into defence requirements is really important. But any sort of decision on any investment in space has to follow the terrestrial requirements. What sort of warfare do you want to engage in? What can be provided by our allies that we have already integrated and always integrated with? And what is it reasonable to afford? Any investment in space is going to have opportunity costs elsewhere, because there is a finite budget. I would be worried that there might be some excessive investments in some areas, like in getting an amazing picture of the battlefield, but you have neglected core combat capabilities. It may give you a good idea of how you are getting attacked by Russian artillery, but you don't have any methods of responding on the ground; you just have a good picture of it. So I would be worried about an unbalanced investment in capabilities. There are investments that I think are worth making in space, but that's if they meet terrestrial priorities. I hope that the integrated review manages to outline those terrestrial priorities, because whatever your terrestrial priorities are, there will be space capabilities of some kind that can be created to meet them. But space has to follow the terrestrial priorities.

Chair: Thank you. We have spoken about alliances. Stuart, do you want to probe this a bit further?

Q47 **Stuart Anderson:** Yes, we have mentioned this, but I want to drill down. How do the space capabilities and policies of our allies contribute to UK space security? Todd, I know you just spoke about the partnerships, so it's not just one country that you would be taking on; it's all. But I would be keen to hear your views on this, Alexandra.

Alexandra Stickings: They contribute hugely—it's quite simple. If you just look, for example, at GPS, which is a US system that the UK uses, this plays a role not just in defence, but in transportation systems, the internet, the international financial system—all parts of UK society rely on it. Again, with Earth observation capabilities, the applications are vast. It's actually really difficult in some ways to find something that does not rely on space in some way. It's really impossible to separate, I think, our reliance on that from any sense of our security and our defence. But again, I think it's important that we recognise that while it is to the benefit of our allies to allow us access to this, we cannot just be completely blindly dependent. It is about these questions. What are we bringing to those partnerships? What are we adding value to? How are we ensuring that they want to continue with us having access to those systems? Again, there is a role to play. There's the purely US partnership, there's Five



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Eyes, there's NATO—there are quite a few different partnerships and alliances that the UK has to navigate. So it's a question of thinking not just about where we are getting all these signals and this information from, but about how those alliances might shift and change as we move forward and how conflict—where we are fighting and how we are fighting—might affect them. That will help us to navigate where we can continue to rely and where we might need to add our own capabilities in.

- Q48 **Stuart Anderson:** Todd, I will come to you in a minute—I saw your hand there—because this will link nicely. You mentioned all the different alliances. What does the US space defence strategy mean for the UK's space security? Alexandra, could you answer this first? Todd can then follow up.

Alexandra Stickings: I think it comes down to something that I mentioned earlier: the extent to which the UK will go down the route of war fighting and conflict in space. That is the decision. The US is arguably the most important ally in space for the UK at the moment, in terms of our dependencies and that very close relationship. However, there are implications for the UK in terms of how closely it wants to align itself with the US in those concepts. As I mentioned earlier, would the UK go down the route of developing its own offensive capabilities? If a US satellite is affected in some way, how might the UK be expected to respond? Will it respond? It comes down to how the UK decides to position itself as a space power. Is it about military, defence and power projection, or is it more along the role of the international diplomatic side? I think it is making the UK ask that question.

Todd Harrison: One of the things that is articulated in the US space defence strategy is the importance of allies and partnerships in space. I might disagree with the other panellists a bit here, but I would say that the UK does not have a decision about whether it wants to fight in space. Our adversaries are making that decision for us. Our question is: do we want to be able to defend ourselves in space and to be able to continue to use our space capabilities? Whether or not we fight in space is a decision that is really up to Russia and China, quite frankly, and they have made it pretty clear where they fall on that.

To pick up on something Ali said, one of the most important things is that we have to do a better job—as a community and a consortium of allies and partners—at defining norms of behaviour in space. I like the analogy that I have heard people use before: norms in space are like speed limit signs. Speed limit signs do not stop people speeding; they just let you know who the speeders are. Norms of behaviour in space are similar, because we have to reach common agreement among like-minded nations on what is acceptable behaviour in space and what is not acceptable behaviour. We do not have to cover everything and every possible contingency, but if we could cover some of the important things—such as remote proximity operations, interfering with other people's space assets, and debris-producing attacks—on which we can have common agreement, we should. We have to articulate those norms in advance, and we have to observe them ourselves. That is important. Once we do those things, it will make it



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much easier to call out and identify the bad actors, to make sure that we all agree on who the bad actors are and what they did that was wrong. That is the first step to being able to respond and to being able to adequately defend ourselves in space.

- Q49 **Stuart Anderson:** I am conscious of time, so I will make this quite quick. You talked about like-minded countries. We also have Russia and China in the equation. How is the US's goal of space superiority compatible with achieving space stability, or do they conflict?

Todd Harrison: I think we have to view the military terms "space superiority" or "space dominance" in the context of how we use those terms in other domains. When we talk about air superiority, we are not talking about shooting down every aeroplane everywhere in the world. Unfortunately, I think that is where people's minds go when it comes to space superiority. It is not about taking control of anything; it is about having the capability whereby, if we need to, we can own the airspace in a localised area for a certain period of time. It is similar in space, where, if we need to, we should be able to control what is going on for a period of time in a certain place in space in order to further our military objectives. It is not a blanket thing. It is not something you would do all the time—you would not exercise this in peacetime. It is just having that capability.

I do not think that that is incompatible with stability and deterrence in space—in fact, I think it enables it. If we can show adversaries like Russia and China that their attacks are not going to be effective because we can blunt them and fight back, and that our military objectives will proceed on the ground regardless of what they are doing, that is the strongest thing we could do to deter attacks in space and maintain stability in the space domain.

- Q50 **Chair:** We are coming to the end, but I have a quick question, if I may. A lot of this is to do with the rules, and there is an absence of rules in space. First, is it achievable for us to try to develop an international understanding and some norms? Ultimately, this will become an ever-increasing problem unless there are some international standards that we are able to follow.

Dr Bledwyn Bowen: I think it is always worth trying to build norms and rules where there are not any or where there is a vacuum—excuse the pun. It is certainly worth trying, but there are real problems and limitations in trying to do so. In the past, there have been some top-down initiatives from the EU and the United States on the international code of conduct for space activities, and they did not go down too well with the international community at large, who saw it as a top-down imposition of how to do space operations, especially on the civilian and commercial side, but it also tried to regulate military space activities.

We also have the Russian and Chinese PPWT, which is their treaty-based approach to try to ban space weapons broadly defined in space. They see that as a way to try to build rules in space. There are many flaws in that approach, and that has been stalled for a good 40 years.

On the new British effort at the UN General Assembly, I think it is good in that it is trying to build consensus from what the UN General Assembly thinks are the problems worth solving. It is not producing solutions yet, but it is trying to build a bottom-up approach. I would be concerned, however, to stay away from the military side of it; I think we have to keep it to civilian and commercial everyday benign operations where you will find the most common ground, to avoid any accidental issues or miscommunications. I would be very worried, especially given the language in one of the Government's press releases recently that tried to frame it in terms of preventing an arms race in outer space. That will trigger Russia to say, "No, you will sign this treaty or you will not get our help on your norms initiative." So I would be very wary that that might get hijacked by the PPWT effort.

But I definitely think that the effort is worth making. At least if we get a common understanding of the problems, we can start looking at the next step, if we get that far. I definitely support the general idea, but I would be very worried where the rhetoric might involve the military too much.

Alexandra Stickings: We should be trying. One of the problems that has been faced is that, through the PPWT, they are trying to create an overarching treaty. Bleddyn just talked about an arms race in weapons, and the difficulties that come with that. Beyond the political difficulties, of which there are many, are: how are you defining a weapon and what parameters are you using for those capabilities? We need to start small and move forward.

We have had voluntary guidelines in the past, particularly around debris mitigation. These have worked to some extent, but they are voluntary, so not everyone is going to come on board. Bleddyn mentioned the commercial sector. This is very important. They have experience in operating in space, and we should be bringing the commercial operators into the conversations around those responsible norms of behaviour.

Start small as well—again, don't look too big. One area that I have heard discussed is around rendezvous and proximity operations, with the concerns about satellites approaching others. Could there be an agreed minimum distance where, if you cross that threshold, you are in your rights to say, "You are too close to me. I feel threatened in some way"? You can start to build agreements on these more specific areas, and start to get consensus and a bit of international co-operation on trying to create a safer environment, which might eventually lead to slightly bigger agreements. But I would be very sceptical of whether any overarching treaty that includes hundreds of states is actually achievable.

- Q51 **Chair:** Todd, turning this around, we learned that Skynet is absolutely critical for our military communications. It also allows our ambassadors in Washington DC to communicate securely with the UK, unless somebody chooses to share them. Is it possible to watch these things in space, so that we can actually identify when an aggressor comes in and does something and therefore we can appoint blame, so that by having it in view—surveillance, if you like—we are able to somehow defend it better?



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Todd Harrison: Technically, it absolutely is possible. Your ability to watch from the ground for objects in geostationary orbit is somewhat limited, but the United States, for example, has satellites in geostationary orbit, called the GSAT programme, that are inspector satellites. They drift around the geobelt, they can get an up-close look and they can help to determine and characterise what these other objects in space are and what they are doing.

You can also install capabilities on your satellites before you launch them that give you better situational awareness of what is going on around you, not just in terms of visual picture, but radar and the RF environment and whether there are things transmitting to you from different locations that maybe are not supposed to be there. Technically, it absolutely is possible. We need to do more of that—we need to start building these capabilities into future space systems, but I think that will take a generational update.

To go back to your original question about future international agreements for a moment, I am not optimistic that we are going to get a larger international agreement like the outer space treaty, where we bring all the countries together and we agree on certain parameters for how we are going to operate in space. The Russian and Chinese PPWT proposal at the United Nations is beyond hypocritical. Russia is already violating exactly what it says it wants to prohibit, and it only prohibits space-based weapons, not terrestrial-based ones. The EU code of conduct had its own problems; it was limited to just kinetic forms of attack and did not address the many forms of non-kinetic attack within space systems.

Ultimately, we are going to have to have norms of behaviour that evolve gradually over time, where like-minded nations come together and start operating in a certain way and that becomes more and more accepted. I would point out there is one initiative that the United States is pushing now that I think is a good idea: the Artemis accords, proposed by NASA and our State Department, which is a set of principles that countries will have to sign up to in order to be part of the Artemis programme to go back to the moon. Many of those principles relate to how we are going to operate on and around the moon, but some of them relate to how we operate in Earth orbit as well. That could be a good starting point to bring countries together to start to reach some sort of further agreement on how we are going to operate in space.

Chair: Much to consider, not least because everybody is heading back to the moon now, so no doubt we need some rules and regulations for that. Perhaps we need a UN white helmet satellite system—maybe that is the answer here. Thank you very much indeed; it has been a really fascinating inquiry session today, and I am grateful to all the panellists and to my Committee. Thank you, Todd Harrison, Alexandra Stickings and Dr Bleddyn Bowen, for your time today. That brings this Defence Committee inquiry to an end for the moment.