
Space spectrum strategy - annex

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A1. Overview of consultation responses

- A1.1 We received consultation responses from 38 respondents. Three of those respondents submitted confidential responses, with a further four respondents submitting responses which included some confidential material. One respondent submitted both a confidential and a non-confidential response. All [non-confidential responses](#) are published on our website.
- A1.2 We have carefully considered all responses in finalising the updated space spectrum strategy set out in the main body of this document. This annex summarises the main points made by stakeholders in their submissions and sets out our assessment of those points, as relevant.
- A1.3 We asked eight questions in the consultation. In some cases, respondents opted to structure their responses without specific reference to the particular questions we posed. In other cases, respondents made the same or similar points in their answers to more than one of our questions. In all cases, we have collated comments made about the same issue and addressed them together in the most appropriate part of our overall assessment below.
- A1.4 It was clear from the consultation responses we received that the rapid expansion and development of NGSO satellite systems - particularly NGSO constellations of hundreds or thousands of satellites – was seen by stakeholders as the most pressing and significant issue to address in managing space spectrum in the next few years. A significant majority of the comments included in responses related to issues associated with NGSO systems.
- A1.5 This annex therefore considers all comments specifically relating to NGSO systems first, before going on to assess responses related to other areas of space spectrum management. In addressing NGSO issues, we note the distinction between issues related *specifically* to NGSO satellites and issues (such as access to additional spectrum etc) related to both NGSO and GSO satellite systems.
- A1.6 We structure the annex as follows:
- We first consider some **general comments about our proposed strategy** for space spectrum;
 - We then discuss stakeholder responses on the issues we identified in the March 2022 consultation relating to **NGSO satellite communications** specifically, and on the actions we proposed;
 - We then consider responses on other **overall trends in the space sector** (other than NGSO satellite communications) identified in the March 2022 consultation, and on additional trends identified by respondents as important for our space spectrum strategy;
 - We then assess responses related to **our strategic objectives and priorities** (beyond our objectives for NGSO systems) as set out in the March 2022 consultation (i.e. responses on communications, earth observation and space access);

- We then discuss comments on the related **work areas and actions** on which we proposed to concentrate;
- Finally, we note and assess other issues raised by stakeholders.

General comments on our proposed strategy

- A1.7 In general comments on our proposed space spectrum strategy, most respondents said we had correctly identified the important issues for the space sector and that the priorities and action areas we proposed for the next few years were broadly correct.
- A1.8 There was universal agreement that the satellite industry is becoming ever more important for a growing range of sectors.
- A1.9 Respondents noted the great opportunities this presented for the benefit of society and business – but many also had comments on the challenges involved in keeping space ‘safe’ for all users, as the number of satellites in orbit around the world proliferates.
- A1.10 Other key themes mentioned in general responses on our proposed space spectrum related to competition issues and to coexistence between different space users and between space users and other users of the spectrum.
- A1.11 Some respondents identified areas of the space sector they felt had not been given enough attention in our proposals overall - most notably, these comments related to communications to support lunar operations and space exploration. For example, the UK Space Agency and Department for Business, Energy and Industrial Strategy (BEIS) noted the UK Government's commitment to working with others on revisiting the Moon, and said spectrum requirements for this needed to be considered in our strategy. This view was supported by Lockheed Martin and Northumbria University.

Ofcom assessment

- A1.12 We welcome the general support for the analysis and proposals we set out in our March 2022 consultation.
- A1.13 We agree with the comments about the importance of understanding spectrum needs for lunar communications and space exploration and have amended our plans to take account of this. We address these issues in section 4 of this annex. We address comments about other general issues below.

International engagement

- A1.14 Many general comments by respondents focussed on the importance of international engagement. Overall, there was wide recognition that recent trends – particularly the development of NGSO systems – were global in nature and required global agreements through the International Telecommunications Union (ITU).
- A1.15 Many stakeholders commented positively on Ofcom's on-going involvement in international bodies, with some urging us to adopt particular courses of action in support of their own sectors. Some were anxious to ensure that Ofcom did not introduce

regulatory changes inconsistent with international agreements that could confuse investors or limit the market.

- A1.16 Inmarsat and Northumbria University said it was important that Ofcom was fully aligned with other UK agencies and strategies, such as the UK Space Agency and the UK Government's own strategy for space. They suggested the UK Government's [National Space Strategy](#) should in itself be a major driver of Ofcom's strategy. For example, our approach towards international regulations should be aligned, including on support for the development of new rules enabling ongoing global operation of new satellite systems.
- A1.17 In its own response, we note the UK Space Agency and BEIS said of the March 2022 consultation: *"We were pleased to see this consultation is largely in agreement with our analysis and aspiration"*. However, they added there was a pressing need to set out a clear national position on the relevance of international agreements to our national stance. There was also a need to implement Government policy on national security and national interest.
- A1.18 Among others addressing the international nature of satellite issues, the Royal Astronomical Society urged Ofcom to secure greater - and routine - collaboration between the ITU and the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in the specific area of satellite constellations, and their wider impact on the science of astronomy.
- A1.19 Northumbria University pointed to the importance of UK led discussions on UNGA Resolution 75/36 on Reducing Space Threats Through Norms, Rules, and Principles of Responsible Behaviours. Further, as counter-space capabilities including electronic jamming and spoofing expanded, it said it was important for Ofcom to continue this leadership in supporting space security. It was important for Ofcom to not only monitor what is happening regarding the Long-Term Sustainability Guidelines¹ but Ofcom should also coordinate with other UK departments on implementation.
- A1.20 Northumbria University suggested broadening the scope of the UK Satellite Consultative Committee to enable a more long-term, forward-looking approach to establish objectives for Ofcom.

Ofcom assessment

- A1.21 As set out in the March 2022 consultation, we recognise the global nature of the space industry and agree with those respondents who stressed the importance of proactive engagement with international bodies. We represent UK interests at the ITU, including at World Radiocommunications Conferences (WRC) where we lead the UK delegation.² We

¹ Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space, UN [doc A/74/20](#) Appendix II, p 50

² See Annex A to Memorandum of Understanding at: http://stakeholders.ofcom.org.uk/binaries/international/mou/MoU_2004_International_Rep.pdf. We also represent the Channel Islands, the Isle of Man and the British Overseas Territories at the ITU, see http://stakeholders.ofcom.org.uk/binaries/international/mou/MoU_OTs_2007.pdf

also represent UK interests at the European Conference of Postal and Telecommunications Administrations (CEPT).

- A1.22 We engage with our stakeholders (who come predominantly from Government, industry and academic fields) to enable us to represent UK interests in these forums. We also take account of wider UK public interests in our international representation work as we consider appropriate. We are committed to taking a leading role within international bodies to ensure the UK's interests are supported.
- A1.23 Our international engagement is shaped by our statutory duty to manage the UK radio spectrum, having regard to securing its optimal use. For us 'optimal use' means that spectrum is used in a way that maximises the benefits that people, businesses and other organisations derive from its use, including the wider social value of spectrum use.
- A1.24 However, in respect to space, various Government bodies, particularly the UK Space Agency under BEIS, determine national policy more generally. Ofcom's own statutory duties related to space are limited to spectrum use, and complement but do not duplicate the work of other Government agencies.
- A1.25 We recognise the importance of a unified UK approach to international issues for space spectrum and engage with all relevant departments, groups and industry in shaping our input into WRC and other bodies. We consult widely and consider the views of various interested parties on UK positions and priorities.
- A1.26 We will also be working with the UK Space Agency and other government bodies to better understand the linkages between spectrum and broader space sustainability and safety issues and where appropriate coordinate the UK approach in international forums on these issues.
- A1.27 Within the UK, we make policies in accordance with international agreements. We reserve the right to adopt our own national positions on spectrum matters that are limited to the UK alone – including on such matters as setting UK licence conditions – but ensure these decisions do not cut across international agreements.

Spectrum sharing

- A1.28 Our consultation focused on the importance of spectrum sharing in our proposed space spectrum strategy, consistent with Ofcom's approach to spectrum management more generally. On this point the UK Space Agency and BEIS said there was a risk that placing priority on spectrum sharing and the accommodation of other users undermines the perceived value of international filings. They said greater priority should therefore be placed on recognising the value of being 'first to market' (and therefore recognising the market driver for investment) while still striving for technical means to improve sharing.
- A1.29 Inmarsat said a high priority item for Ofcom should be to ensure that shared satellite spectrum is free from interference from other (i.e. terrestrial) users. It said this was not currently identified as a priority in the tables we presented. It also said the position adopted by Ofcom on 5G spectrum was "potentially extremely harmful" to satellite use of certain frequency bands, including the 28 GHz and 48 GHz bands. It said there appeared to

be a major disconnect between Ofcom's proposed space spectrum strategy and its approach to mobile.

- A1.30 Inmarsat made similar points in respect to discussions over use of the upper 6 GHz band. It said Ofcom's position so far was neutral, despite that fact that important UK services, including services widely used for safety, emergency and disaster relief are, in its view, threatened. It argued that a consistent strategy for these bands would see Ofcom supporting action at WRC-23 to ensure that satellite use of these bands is not threatened by terrestrial services.

Ofcom assessment

- A1.31 Radio spectrum is a scarce and valuable resource. Advances in wireless technology mean ever more uses of spectrum for communications and other services are being developed, creating ever greater demand for available spectrum. Our statutory duty to ensure the optimal use of spectrum means we seek to ensure radio frequencies are used as efficiently as possible.
- A1.32 Our 2021 [Spectrum Management Strategy](#) – which provides the framework for our overall approach to spectrum management - identifies the promotion of spectrum sharing as an important element in that drive for efficiency, wherever it is possible. Enabling more users in the same or adjacent spectrum bands is inherently more efficient and beneficial, so long as we can achieve this without unreasonably degrading the quality of services provided. We therefore need to secure an efficient balance between the level of interference protection given to one service and flexibility for others to transmit.
- A1.33 In achieving that balance, both elements - flexibility and protection - are important. We therefore accept that the drive for efficient use of spectrum through sharing should not undermine established international processes (e.g. on satellite filings) or put services already launched at risk.
- A1.34 We note that the ITU's satellite filing process also encourages sharing. It does not seek to limit the number of operators that can file for particular frequencies or the number of satellites that any one filing can encompass. Operators are required to coordinate with those who hold more senior (i.e. earlier) filings, but all parties are expected to negotiate in good faith.
- A1.35 In principle, sharing is about being a 'good neighbour'. One aspect of being a good neighbour is for the emissions of transmitters to be limited appropriately to ensure interference to other users is minimised. Another is to ensure that systems are as good as they can be at protecting themselves from interference.
- A1.36 However, we acknowledge that sharing may not always be possible in all circumstances. Where that is the case, Ofcom will continue to ensure appropriate protections are in place for already established services and that conditions are enforced.

A2. Responses on NGSO satellite communications

A2.1 As noted, the primary area of attention identified by stakeholders in their consultation responses was how we should respond to the opportunities and challenges introduced by new NGSO satellite communication systems. In our March 2022 consultation we said our future work will have a particular focus on these systems and proposed an objective specifically relevant to NGSO satellite systems. We said:

"We aim to enable as many NGSO systems as possible to provide services in the UK. We have already made changes to our licensing process and there are several other issues that may need to be addressed to support efficient spectrum use by NGSO systems."

A2.2 We set out the issues and action areas we proposed for NGSO satellite systems as follows.

Issue	Action
<i>Spectrum access for NGSO systems</i>	
Spectrum access for NGSO earth stations	<ul style="list-style-type: none"> Consider updating earth station network licences, ship and aircraft licences so that NGSO ship and aircraft earth stations can broadly use the same frequency ranges that are already available for GSO use.
International regulations for ESIMs	<ul style="list-style-type: none"> Remain supportive of work on WRC-23 Agenda Item 1.16 studying NGSO ESIM provided that incumbent services remain adequately protected.
<i>Efficient use, sharing and assurance for NGSO systems</i>	
NGSO-NGSO sharing: Improvements to International (ITU) framework	<p>Seek international changes to:</p> <ul style="list-style-type: none"> Create guidance on how much interference NGSO systems should be prepared to accept from one another; Increase the certainty around the changes NGSO systems may need to undertake during their lifetime, including by: <ul style="list-style-type: none"> ➤ Quantifying how much the orbital characteristics of a NGSO system can deviate between what has been recorded by the ITU and the actual operation; ➤ Quantifying how much a NGSO system can change its characteristics without affecting its coordination status and relative date of priority, and; ➤ Ensure recorded satellite numbers remain up-to-date through the lifetime of a NGSO system, and that the associated rights to orbital resources match the actual satellites deployed.

<p>NGSO-NGSO sharing: Handling of interference</p>	<ul style="list-style-type: none"> • Develop our national interference monitoring capabilities and our understanding of the resilience of NGSO systems to interference. • Continue to promote the development of globally harmonised approach through ISRMM and the ITU.
<p>NGSO-NGSO sharing: Evolution of national NGSO licensing regime</p>	<ul style="list-style-type: none"> • Extend our NGSO licensing regime to additional bands (e.g. 14.25 – 14.5 GHz) when we make them available. • Consider opportunity cost of NGSO systems when we next review the pricing of satellite earth station licences.
<p>NGSO-GSO sharing</p>	<ul style="list-style-type: none"> • Introduce licence terms to put conditions on NGSO downlink. • Developing our capabilities for handling NGSO to GSO interference. • Continue to support improvements to the way NGSO systems are modelled when assessing their interference potential towards GSO systems.
<p>NGSO downlinks sharing with Radio Astronomy</p>	<ul style="list-style-type: none"> • New licence conditions to ensure protection of radio astronomy. • Develop a new approach to handling of NGSO interference to Radio Astronomy.
<p>NGSO systems sharing with fixed links</p>	<ul style="list-style-type: none"> • Continue to engage in studies (as part of WRC-23 Agenda Item 1.16) on sharing between NGSO ESIM on aircraft and ships and fixed links.
<p><i>MSS NGSO communication systems below 1 GHz</i></p>	
<p>MSS NGSO communication systems below 1 GHz</p>	<ul style="list-style-type: none"> • Consider moving national authorisation from exemption to light licensing. • Support reform of the CEPT framework for MSS systems below 1GHz. • Monitor WRC-23 agenda item for new MSS allocations.

A2.3 We asked stakeholders the following related questions:

Question 6: Are there other issues and actions specifically relating to NGSO communication systems that are likely to be important over the next 2 – 4 years?

Question 7: Do you have any evidence on whether specific actions relating to NGSO communication systems should be a high priority?

Question 8: Do you have any other comments relating to NGSO systems?

Consultation responses

- A2.4 There was broad agreement with our identification of NGSO satellite constellations as a very significant recent trend in the space industry, warranting particular attention. Many respondents said NGSO satellites are fundamentally changing the space environment for the future and noted the importance of addressing relevant issues sooner rather than later.
- A2.5 For example, the Royal Astronomical Society said the impact of large satellite constellations on astronomy was significant with limited mitigation and no formal international regulation. Maxar and Aurora said new generation NGSOs “posed the most complicated regulatory concerns” in their demand for high bandwidth, extensive and varying geographic coverage, and time-based demand. It noted that communications NGSOs serve very different purposes to legacy GSO systems and now dominate spectrum requirements.

General comments about NGSO satellites

- A2.6 Although many respondents recognised the potential benefits and opportunities presented by NGSO systems, there were concerns in particular about the coexistence of NGSO satellites with existing and future services (both terrestrial and space-based) and between NGSOs themselves. For example, Maxar and Aurora said legacy/incumbent systems may have been designed and fielded many years before NGSO mega-constellations were even considered a possibility. Accordingly, they were not designed for resilience and coexistence with NGSO constellations.
- A2.7 Respondents also raised wider issues related to NGSO satellite systems including over spectrum availability, licensing, protections for particular services, in-orbit services (IOS) and space debris.
- A2.8 Generally, those stakeholders involved in the development of NGSO systems, such as SpaceX, Amazon, Kepler Communications, Kinéis and CLS said they wished us to be proactive in enabling and fostering their further development. They urged us to engage fully with international bodies to ensure all opportunities to support the growth of NGSO systems were seized.
- A2.9 On the other hand, other stakeholders including Inmarsat, Met Office, Royal Astronomical Society and Viasat urged us to ensure that the development of NGSO systems was not allowed to disrupt their own operations, which they said were of great value both to the UK and to customers globally.
- A2.10 Viasat also provided comments on a wider range of issues, many of which were raised by others, including competition concerns, interference issues, collision danger, and risks to national security. Viasat said appropriate action taken by Ofcom now would be an important, necessary, and critical first step toward managing risks in the short term.

- A2.11 The UK Space Agency and BEIS said the big expansion in the space sector presented important issues for sustainability that needed to be addressed. Many other respondents raised issues of particular concern to their sector.
- A2.12 Arqiva said that, while supportive of the benefits NGSO satellites can deliver, it did not want to see the development of any one NGSO system unnecessarily preventing the operation of other systems.

Differing types of NGSO systems

- A2.13 Methera and SES said the March 2022 consultation used the term NGSO throughout the document to refer almost exclusively to Low Earth Orbit (LEO) systems. Methera said the reality was that challenges related to spectrum sharing needed to also consider medium Earth orbit and highly elliptical orbit NGSO systems.
- A2.14 SES agreed and said that not all NGSO systems would be mega-constellations. Nevertheless, it fully subscribed to Ofcom's intention to foster competition in the satellite sector and enable as many NGSO systems as possible to provide services and increase choice.
- A2.15 The UK Space Agency and BEIS said it was highly likely we will see hybrid systems operating in future in all orbits. It will require some thought on the management of agile communications links between GEO/MEO/LEO "in a way we may not have considered to date".

Monitoring spectrum use

- A2.16 Lacuna Space said monitoring new developments and how satellite operators act in spectrum sharing remains one of the most important topics for the next years. Maxar and Aurora said there was a need for more advanced monitoring of NGSO constellations and their emissions to provide better understanding of both their operations and their impact. Measurement of actual spectrum use - including over frequency, geography, and time - would greatly enhance understanding of issues for sharing. This would help provide clarity on the requirements placed on new systems.
- A2.17 Maxar and Aurora added that new high-bandwidth communications NGSO systems, with hundreds or thousands of satellites, are technically complicated in that they serve many users in an area with high bandwidth, and have requirements for seamless handoff as the satellites come in and out of a service area. Compliance with restrictions on the number of active simultaneous downlink beams and the maximum power flux density should be effectively measured and monitored to avoid interference issues.

Monitoring future developments

- A2.18 Kepler Communications said it was important that Ofcom continued to remain aware of changes in service offerings in bands used for NGSO satellites, and to stay up to date on new markets that are under development - such as space utilities for in-space assets. It said we needed to be in a position to react accordingly at appropriate times.

A2.19 The BBC also urged us to monitor global trends to assess any impact on UK stakeholders. It noted that “for every licensed uplink there is a large number of unregistered downlinks” which can impact on services.

Ofcom assessment

A2.20 The general comments of consultation respondents about NGSO systems reflect many of the issues we identified in the March 2022 consultation, and the points identified above are not at odds with our proposed space spectrum strategy.

A2.21 The concerns noted by respondents reflect the main issue at the core of our space spectrum strategy i.e. finding the right balance between enabling new and innovative services at the same time as ensuring existing valuable services can continue.

A2.22 Our March 2022 consultation focussed on LEO constellations because they presented both significant new opportunities and significant concerns for existing space operators: a judgement supported by the large volume of consultation responses focussing virtually entirely on NGSO constellations.

A2.23 We note that LEO constellations are the ones most likely to deploy in the next 5 years, often launching very large numbers of satellites. However, all NGSO constellations are more dynamic than GSO systems and have an increased risk of inline events, and are therefore more complex to coordinate. The new NGSO licensing process we have introduced applies to all NGSO broadband services.

A2.24 To be clear, we understand that NGSO by its definition includes all orbits apart from Geostationary Orbit (GSO). We recognise that NGSO satellites in other orbits, including constellations, face much the same issues over coexistence as those in LEO.

A2.25 In addressing all these issues for the future, we note the importance of monitoring and understanding both the ‘real-life’ use of spectrum in space and the development of the market. Only by understanding both of these factors can we be sure to reach appropriate decisions on regulations, and adopt the most appropriate positions for the UK in future in international discussions.

Spectrum access for NGSO systems

A2.26 Our March 2022 consultation discussed options for access to additional spectrum for satellites. We identified the Ku band³ and more particularly the 14.25-14.50 GHz frequencies within that band and subsequently [consulted](#) on specific proposals. We also noted interest in the Ka band⁴, including the 28 GHz frequencies; and interest in opening up spectrum in the Q/V bands⁵, primarily for gateway earth stations.

³ Ku band spans 12-18 GHz, but for space purposes is commonly considered as around 14 GHz for Earth-to-space and 11 GHz for space-to-Earth

⁴ Ka band spans 26.5-40 GHz but for space purposes is commonly considered as around 30 GHz for Earth-to-space) and 18 GHz for space-to-Earth.

⁵ Q/V bands span 33–75 GHz. Use for satellite is in Q band ranges 37.5-43.5 GHz, and V band ranges 47.2-50.2 GHz and 50.4-51.4 GHz.

A2.27 These spectrum bands may be used for a variety of satellite operations, for GSO systems and not just for NGSO systems. For this reason we address issues about access to additional spectrum within subsections below on communications more generally.

NGSO satellite filings

Proliferation of filings in Low Earth Orbit (LEO) and impact on competition

- A2.28 A common theme in the consultation responses was the potential domination of the space industry by one or two major operators. Responses linked this concern to the congestion of LEO in terms of spectrum access (see also responses on NGSO-NGSO sharing below) as well as physical congestion of orbits (see also responses below on space debris and sustainability).
- A2.29 Northumbria University said congestion of LEO was now a serious issue. Continuously updating the LEO governance framework through ITU and UN COPUOS, with input from the UK, would ensure Ofcom and other departments keep regulations up-to-date and harmonised internationally.
- A2.30 Tech UK expressed similar concerns, saying Ofcom should focus on ensuring there were no loopholes in ITU-R Radio Regulations. It said Ofcom should help to avoid the proliferation of massive NGSO constellation filings endorsed by other administrations, which may represent a new way to introduce "paper satellites". It asserted that as the space industry progresses towards 5G, and eventually 6G, this is an important ask. It cautioned against allowing mass NGSO filings by big companies to crowd out late entrants and other users.
- A2.31 Methera, on the other hand, said it supported Ofcom's aim to see as many NGSO systems as possible and considered that a natural supply/demand equilibrium will eventually be reached, depending on numbers of operators and numbers of markets/market sizes. The ITU, Ofcom and other regulators "cannot and should not be the bodies who influence this settling point". However, it contended that methods of coexistence which are fair to all must be developed, agreed, and implemented.
- A2.32 Viasat said the operation of very large constellations by one or two operators would not only prevent other satellite operators or constellation projects from competing effectively, it could also have a significant negative impact on the entire UK space and telecom industry. In Viasat's view these effects would be exacerbated when a LEO operator employs a vertical integration strategy, keeping 100% of the value of the project for itself.
- A2.33 It said Ofcom should not assume that risks to British interests will be adequately addressed by other administrations of NGSO systems. On the contrary, other nations have incentives to fully populate LEO before the UK and other countries. It said at this early stage of the 'New Space Age' we are seeing *"a few actors in LEO staking claims to vast amounts of orbital resources in a manner that risks freezing out competition from, and innovation by, others."*

Ofcom assessment

- A2.34 We note the concerns of some stakeholders about mass satellite filings for LEO mega-constellations. As stated in the consultation we want to enable as many NGSO systems as possible, to provide services and increase choice for people and businesses in the UK.
- A2.35 We do not agree that deployment of NGSO systems with high numbers of satellites is necessarily a barrier to competition. This is because such systems have, in principle, greater diversity of paths between terminals and satellites, and so can more easily avoid harmful interference to or from other systems. However, operators of very large constellations could prevent or make it harder to achieve equitable access to certain orbits and frequencies.
- A2.36 In particular, earlier filed systems, including but not limited to those with high numbers of satellites, may lack incentives to accommodate competitors with later filings. These systems might seek to use their regulatory status to place unreasonable constraints on later filed systems, for example by using a large constellation to block rather than facilitate coexistence with others, or, for example, demanding very high levels of protection from later filed systems (as noted in the March 2022 consultation).
- A2.37 Such an approach is contrary to the aims of the ITU (which refer to equitable use of spectrum and orbital resources)⁶ and its procedures⁷ for coordination between satellite operators. These make it clear that while coordination is the responsibility of the later filed system, the negotiations should be a two-way process. All operators (including earlier filed ones) need to negotiate in good faith in order to enable the most efficient use of spectrum.
- A2.38 For example, our view is that operators with very large constellations need to engage in a two-way discussion with later filed smaller constellation in order to find opportunities for sharing spectrum, rather than expecting the full burden of coordination to fall on later systems. This is because the larger constellations will have a greater ability to avoid inline events/interference.
- A2.39 We have both a national and international response to the issues raised.
- A2.40 **Nationally** we have a liberal domestic licensing system which recognises the benefits of granting NGSO licences for consumers in the UK, but also includes a competition check to deal with cases where granting a licence (or licences) could have competition risks. In addition, our NGSO network licences (which all operators wishing to serve the UK must hold) contain a condition requiring them to cooperate with other NGSO licensees, which reinforces the ITU expectation that coordination negotiations should be a two-way process between operators. Finally, they also allow us to deal with cases of interference between NGSO systems causing a material and recurring degradation of services to users in the UK. This could include cases where an earlier filed very large NGSO system causes interference to a later filed small NGSO system.

⁶ <https://www.itu.int/council/pd/constitution.html>
https://www.itu.int/dms_pub/itu-r/opb/reg/R-REG-ROP-2021-R02-PDF-E.pdf

- A2.41 **Internationally**, our approach is to focus on improving and strengthening the international framework for NGSO satellite systems in order to facilitate efficient sharing of spectrum between these systems. We will continue to engage on a number of issues through the ITU to support this aim, including those set out in the March 2022 consultation. We will continue to work with stakeholders on these issues through relevant international (e.g. ITU Working Party 4A) and national (e.g. IFPG WG3) forums. We will consider working on other improvements to the international framework where they can advance our aims to enable as many NGSO systems as possible, and ensure efficient sharing of spectrum between such systems and other spectrum users.
- A2.42 With reference to Northumbria University's points on liaison with UN COPUOS and ITU, we will continue to work with UKSA and other government bodies to better understand the linkages between spectrum and broader space sustainability and safety issues, and, where appropriate, coordinate the UK approach in international forums on these issues.
- A2.43 In relation to Viasat's concern about SpaceX's vertical integration, Ofcom is keen to enable NGSO satellite services in the UK and to foster a competitive market for several operators to provide services (as noted in section 2 of the Space Spectrum Strategy). Enabling multiple NGSOs to operate in the UK is likely to be beneficial for the UK. In addition, in principle, vertical integration can result in efficiencies and can, in some cases, be viewed as beneficial for competition and therefore beneficial for people in the UK.⁸ These efficiencies can include reduced costs, and improvements to product or service quality.⁹

Other issues related to NGSO satellite filings

- A2.44 Methera commented on the administrative burden faced by operators in dealing with filings by other operators. It said NGSO systems with current filings faced significant daily e-mail correspondence from national regulators/administrations representing not just licensed satellite operators, but from those requesting (or even planning to request) new ITU allocations. It urged Ofcom to take a proactive role within the ITU to explore ways to avoid this burden by enabling more pragmatic coexistence processes between satellites in NGSO systems and in GSO systems.
- A2.45 OneWeb said the ITU filing regime recognised that those with earlier-designed technologies cannot predict the future, thus cannot foresee the 'growth' that might come. However, future technologies should be able to adapt to existing users and systems. With the shorter lifetimes of their satellites - 6 to 8 years as compared to 15 years for GSO

⁸ See for example, OECD publication 'Vertical mergers in the technology, media and telecom sector – Note by BIAC', June 2019: [pdf \(oecd.org\)](https://www.oecd.org/).

⁹ Efficiencies may include, but are not limited to, a reduction or elimination of transaction costs (i.e., costs associated with contract writing and monitoring between firms at different levels of the supply chain and costs associated with ex ante investment and ex post performance); greater economies of scope; the elimination of double marginalization; improvements to product or service quality; better innovation from coordination in product, design and innovation efforts; the elimination of free-riding from the harmonization of incentives; and the creation of a maverick" – see paragraph 7 of OECD publication 'Vertical mergers in the technology, media and telecom sector – Note by BIAC', June 2019: [pdf \(oecd.org\)](https://www.oecd.org/).

satellites - NGSO systems can evolve and take into account state-of-art technology at a much faster pace than traditional GSO systems.

- A2.46 OneWeb said it was critical that an NGSO satellite operator is able to modify its system without affecting its coordination status and relative date of filings priority. With respect to ensuring recorded satellite numbers remain up-to-date through the lifetime of an NGSO system, OneWeb urged Ofcom against "jumping into another complicated set of provisions" before the 10-year milestones for most systems has occurred.

Ofcom assessment

- A2.47 Given the growing numbers of administrations and satellite operators globally, we recognise the increasing coordination burden on satellite operators.
- A2.48 The onus is on later filed networks to coordinate with earlier filed networks. However, all parties should aim to be spectrally efficient and allow for others to operate, where possible. We agree that NGSO systems do have the opportunity to refresh the design of their satellites and their networks more rapidly. However, as noted above, this can also create uncertainty for later filed networks.
- A2.49 Under the Radio Regulations, NGSO systems can modify their filings if the modification does not increase interference to or from other operators. However, we also recognise that modifications can make coordination more difficult and that predictability is also important if we wish to enable a competitive NGSO satellite market.

NGSO systems sharing with other NGSO systems

- A2.50 The issues raised by the coexistence of new NGSO systems with each other (and with other incumbent spectrum users) were included in many of the responses to our questions on NGSO satellites in the March 2022 consultation.
- A2.51 Amazon said it supported work to develop interference management techniques to investigate NGSO-NGSO interference, and that it agreed with our assertion in the March 2022 consultation that in any investigation of NGSO-NGSO interference there was a need for clear evidence from operators regarding the impact of interference.
- A2.52 Northumbria University said improving the ITU framework as suggested in the March 2022 consultation would also keep up-to-date information on satellites, limit interference, and make actions transparent for space security concerns.
- A2.53 Viasat expressed concerns about the coexistence of large NGSO constellations with other NGSO operations, and urged "equitable access" to spectrum. It said large NGSO systems with thousands of satellites planning to use LEO orbits can consume significant portions of the 'look angles' toward space, and essential LEO orbits, preventing use of the sharing tools that have been employed successfully for decades among NGSO systems.
- A2.54 Viasat said a large NGSO system would rarely (if ever) experience the same issues itself because it is composed of a far greater number of satellites than smaller NGSO constellations. Sheer numbers would provide the large NGSO system with alternative communications paths where the same spectrum remains available for its use.

- A2.55 Repeating some comments it made in respect to competition concerns, Viasat said NGSO system operators were in a race to populate a wide swathe of the “best” orbits (in the 300 km to 700 km range) with huge numbers of satellites in a “land grab”. It said there was a clear threat to NGSO spectrum sharing when large LEO constellations “blanket the sky”.
- A2.56 Kepler Communications said it was important to define specific standards by which interference will be judged. Regulatory certainty should be a core consideration when establishing standards. It said Ofcom had failed to define what would constitute “clear evidence... on the impact of interference”.

Ofcom assessment

- A2.57 We welcome the support from respondents, including Amazon and Northumbria University, on key aspects of our approach to NGSO-NGSO interference.
- A2.58 We have already addressed the key points made by Viasat and others about the scale of NGSO mega-constellation deployment above (from paragraph A2.28).
- A2.59 In respect to the comments of Kepler Communications, we note that the March 2022 consultation stated that investigation of interference will rely on clear evidence from operators on the impact, and that “we expect to provide more guidance on the type of information that we will need from operators.” That remains the case and guidance will be issued in due course.

Approaches to ‘default’ coordination

- A2.60 SpaceX said Ofcom should reconsider its recently-adopted NGSO licensing framework and instead adopt a light touch regime that encouraged private operator-to-operator coordination. On coordinating with other satellite operators, SpaceX said it was wrong to permit earlier filed “paper” systems to hold up deployments. It also accused some operators of using “information requests” in an attempt to obtain unnecessary proprietary and sensitive information for competitive advantage.
- A2.61 SpaceX urged Ofcom to consider “a spectrum-splitting backstop” in the event operator-to-operator coordination is not completed by the time both operators have commenced service in the UK. Under this approach, operators would be required to split the spectrum evenly. Since this approach was not an ideal solution for either party it would drive both parties to find a better option through coordination.
- A2.62 Finally, in the event that Ofcom intervenes in coordination discussions, SpaceX said we should adopt a presumption in favour of more efficient and flexible systems, such as those that use narrow steerable beams designed to mitigate potential for degradation into other systems. Systems with wide, non-steerable beams make cooperation more difficult and should be presumed to be the primary cause of degradation.
- A2.63 Viasat proposed a licence condition requiring ‘look angle’ splitting, whereby NGSO systems serving the UK in overlapping frequencies would divide the range of satellite azimuths, as seen from a location on the Earth, whenever the potential for interference exists at that location. Each operator would bear the same burden by default, in the absence of some

other coordinated outcome. This approach would allow multiple NGSO systems to access and use available spectrum resources on an equitable basis.

Ofcom assessment

- A2.64 As set out in the March 2022 consultation, obligations to coordinate under the ITU Radio Regulations are central to achieving efficient sharing of spectrum between NGSO systems. We recognise that the different mechanisms SpaceX and Viasat suggest are two ways that operators may agree to share spectrum.
- A2.65 However, there are a range of methods which operators may use and, depending on the systems involved, the options proposed may not be the most appropriate or efficient. Other options include requirements for separation distances, satellite diversity, gateway diversity and reverse polarisation.
- A2.66 We do not wish to dictate at this early stage in market development how individual companies may wish to achieve spectrum sharing. In addition, we do not think the UK adopting spectrum splitting as a backstop would create the positive incentive SpaceX suggests. Firstly, spectrum splitting can impact different systems to different degrees, and as a result may be limited in how much it incentivises reciprocal cooperation between systems. Secondly, even if there were in principle a positive incentive to cooperate, as a result of a split being a "less than ideal" outcome for both operators, this would be likely to be very small. This is because a UK mandated split, and hence the incentive, would only apply for services provided into the UK. The UK is a small market compared to the global market served by such operators, and hence the UK outcome would be unlikely to shift their incentives for global coordination.

Orbital tolerances

- A2.67 Kepler Communications said global orbital tolerance was a high priority for NGSO satellite operators. It said it was important that rules were not overly restrictive, given the reality of operating in Low Earth Orbit (LEO). It noted that many small NGSO satellites do not have propulsive orbit-raising capabilities and operate in an ever-decreasing altitude until disposal.
- A2.68 Viasat argued that the preclusive impact of the number of satellites on some LEO constellations would be magnified by the overly wide orbital tolerances within which they propose to operate. It said this effectively fills up hundreds of kilometres of orbits to the exclusion of other NGSO systems that otherwise could operate safely in nearby orbits. It suggested that one mitigation would be to require any LEO operator serving the UK to maintain certain orbital tolerances.

Ofcom assessment

- A2.69 We acknowledge that the absence of orbital tolerances in the Radio Regulations for NGSO systems creates risk of inefficiencies if operators adopt overly wide tolerances, and in the worst case might create limits on the deployment of competing systems. For this reason we are supportive of the proposed introduction of international orbital tolerances for

NGSO systems and we continue to work on this under WRC-23 Agenda Item 7. We remain of the view that this issue is best addressed through an international framework rather than through UK specific requirements (also see discussion below on role of the international framework).

- A2.70 However, we are mindful that any solutions should not be overly burdensome on smaller operators, and should allow legitimate deviations from a satellite's nominal orbit (such as collision avoidance manoeuvres). We would welcome stakeholders' views on the options being discussed through engagement in the relevant international forums.

Role of the international framework

- A2.71 Several respondents supported our approach to improving the international framework for NGSO sharing by working through ITU.
- A2.72 Amazon said it agreed with Ofcom about the need to develop a globally harmonised approach to handle NGSO-NGSO interference. It said the issue of coexistence between NGSO systems will be a high priority in the near future because - unlike the position for GSO networks - there is no existing ITU-R guidance that defines permissible interference criteria between two NGSO systems.
- A2.73 Telesat said whatever methodology Ofcom came up with must be consistent with the ITU framework. Methera said that methods of coexistence which are fair to all must be developed, agreed, and implemented.
- A2.74 OneWeb said it was essential that international consensus is reached on protection criteria, otherwise there was a risk that national rules will create a patchwork of inconsistent approaches. It added the ITU framework provides a well-established process for dealing with interference issues - specifically, that the NGSO system with the later filing should be operated in a manner not to cause harmful interference to earlier systems which operate in accordance with the Radio Regulations. This principle should continue to be the primary means for handling NGSO-NGSO coordination and instances of unacceptable interference.
- A2.75 Viasat, on the other hand argued that action was needed at the national level because international consensus will not be reached on a new framework for regulating large LEO constellations in the short term. It also said that consistent licensing conditions are likely to be an essential part of a global competitive market and suggested that the UK work with other administrations to adopt this type of approach on a coordinated basis.

Ofcom assessment

- A2.76 We agree that the growth of large NGSO constellations, including NGSO-NGSO sharing, presents wider challenges that need to be addressed through improvements to the international framework. As set out in the consultation that will be one of our priorities going forward.

- A2.77 Unilaterally imposing prescriptive licensing conditions at the national level, prior to international agreement, is unlikely to be an effective approach to deal with many of the remaining NGSO challenges identified (e.g. on orbital tolerances).
- A2.78 This is because the solution for many issues will be relevant to the whole of a global constellation and operators may be unable or unwilling to adopt a UK specific requirement. In addition, in the (probably unlikely) event that an operator adopted a detailed UK requirement across their global constellation prior to international agreement, there would be no guarantee that it would match the eventual internationally agreed requirement.
- A2.79 Hence the national licence conditions we have introduced for NGSO systems do not specify detailed requirements but provide a mechanism for us to take enforcement action if there is degradation to services in the UK. If we introduce additional (more specific) conditions into UK NGSO licences in the future we will have regard to relevant international agreements
- A2.80 While we appreciate stakeholders' concerns that international agreement at the ITU can be a slow process, agreeing licensing conditions between multiple administrations is likely to be just as slow and may be fraught with difficulty. Ofcom continues to believe that the ITU forums provide the best opportunity for achieving such international agreement but we are also keen to work with other countries to consider how the relevant international frameworks should evolve.

Spectrum fees for NGSO earth stations

- A2.81 OneWeb, Telesat and SpaceX were among respondents expressing views on spectrum pricing. One Web said spectrum pricing policy on service links had a critical role to play on the adoption of emerging technology, such as that used by LEO satellites. To ensure that the UK remains competitive with respect to hosting earth stations, it was critical to ensure any new fee scheme was not prohibitive.
- A2.82 Space X expressed objections to suggestions in the March 2022 consultation that spectrum pricing should reflect any need for large separation distances required by gateways. It said gateways that can only operate if afforded large protection zones and separation distances will necessarily limit competition. It added that as more consumers require more throughput, operators will require more gateways to support their service. Large separation distances will limit competitors' ability to scale their systems to meet demand.
- A2.83 Therefore, Ofcom should not adopt a fee system that allowed spectrally inefficient operators to 'buy' protection zones around its gateway operations. It said allowing large 'keep-out zones' for a fee would undermine good faith coordination, harm competition, and harm service to end users without any offsetting benefit.
- A2.84 Telesat said the distance between NGSO gateways was entirely dependent on the NGSO systems' parameters. It could not therefore be determined a priori as "large". Furthermore, taking into account the fact that an increasing number of NGSO systems will implement Optical Inter-Satellite Links – which allow constellations to make the most

efficient use of gateway earth stations by limiting their numbers – Telesat said it was of the view that there is a relatively low risk of scarcity of sites in the UK.

Ofcom assessment

A2.85 We note the concerns of some NGSO satellite operators about potential changes to fees. An aim of any change to fees would be to support efficient use of spectrum. As noted in the March 2022 consultation, we do not have any immediate plans to review satellite earth station fees but will revisit the question of fees for NGSO earth stations when we do so.

NGSO systems sharing with GSO satellites

A2.86 In general, opinions on NGSO/GSO coexistence were divided between GSO operators (and those who use or support GSO services) arguing that NGSO systems posed a risk of interference to existing services; and NGSO satellite operators arguing that the existing conditions were, in fact, too restrictive.

A2.87 Nevertheless, most respondents were in favour of changes to international regulations - though some said they preferred Ofcom take action through changes to national licensing.

A2.88 The BBC said NGSO systems may create different interference risks for GSO satellite systems and noted that Ofcom's stated aim for NGSO-GSO sharing is based on the assurance of continued benefits from GSO operations.

A2.89 Two further operators, Inmarsat and Viasat warned of the risk of interference from NGSO to GSO systems. Viasat said the movements of NGSO satellites across the sky created opportunities for time varying interference into GSO networks. It said that unless an NGSO satellite operator employs appropriate mitigation measures, in-line interference events with GSO networks will repeatedly degrade and disrupt services to end users of GSO networks. Viasat considered that even a single NGSO system has the potential to cause interference into GSO networks.

A2.90 Viasat set out a series of actions it urged Ofcom to require of NGSO satellite operators:

- An NGSO system to maintain a suitable GSO arc avoidance angle when serving the UK;
- An NGSO system not to cause unacceptable interference into GSO networks and not to claim interference protection from GSO networks;
- An NGSO system to have an operational feature that allows it to immediately interrupt radio frequency emissions to ensure satisfaction of this non-interference requirement, and to cease emissions upon notice of unacceptable interference; and
- That if interference into a GSO network occurs, an NGSO system must cease operations and not recommence operations until it addresses the cause of such interference by, among other things, increasing angular separation, reducing power, shaping antenna beams differently.

A2.91 Viasat said there was no effective way of ensuring NGSO systems complied with required EPFD limits once in operation, and that the system could be "gamed" by operators. It urged Ofcom to conduct single-entry EPFD examination and verification of compliance against

Article 22 EPFD limits at entry stage on entire NGSO systems, irrespective of the number of ITU filings that make up that system.

- A2.92 Inmarsat said, the use of 'Worst Case Geometry' (WCG) in ITU-R Recommendation 1503 produces results which indicate that some NGSO systems meet the EPFD limits while in fact they exceed the limits in some locations. As a result, there are favourable findings to NGSO systems that lead to potential harmful interference from NGSO systems to GSO systems.
- A2.93 Arqiva supported our proposal to introduce a new licence condition to deal with NGSO downlinks causing harmful interference to GSO receivers. In contrast, Kepler opposed additional licence conditions, saying NGSO satellite operators are already required to comply with the relevant EPFD limits in order to complete coordination at the ITU.
- A2.94 Amazon said it acknowledged the need to ensure incumbent services were adequately protected from NGSO systems, but in contrast to Viasat and Inmarsat said current rules on interference to GSO systems were overly conservative and placed unnecessary constraints on NGSO satellite operators. It urged Ofcom to require substantiation of interference to the GSO network's operations through real technical evidence.
- A2.95 Amazon said it supported UK engagement in international discussions to ensure the evolution of regulations for NGSO-GSO sharing. It said many of the applicable regulations were developed over two decades ago and based on NGSO systems that are no longer in operation. They did not accurately model the operational performance of modern NGSO systems.
- A2.96 It said the current methodology favoured GSO satellites and urged Ofcom to support revision of the current recommendation (ITU-R S.1503). There was support for this position from Telesat.

Ofcom assessment

- A2.97 As set out in the March 2022 consultation, we support improvements to the way NGSO systems are modelled when assessing their interference potential towards GSO systems, although we note that different parties have different views on whether the current methodology overly favours NGSO or GSO systems.
- A2.98 We note Viasat's suggestions for potential actions to manage the risk of harmful interference towards GSO systems. Our licences already require that UK NGSO earth stations comply with the relevant provisions in the Radio Regulations (Article 22) and we have the ability to take enforcement action against licensees who do not comply with their licence conditions in relation to the uplink from the NGSO earth station. This can range from issuing contravention notices and warnings to the imposition fines and/or revocation of licences¹⁰.
- A2.99 As noted in section 4 of the Space Spectrum Strategy, we consider the existing approach to protecting GSO earth stations from harmful interference to be sufficient. However, we will consider whether introducing a new licence condition (into the Earth Station Network

¹⁰ <https://www.ofcom.org.uk/spectrum/interference-enforcement/spectrum-enforcement>

Licence), in relation to the downlink would enable us to enforce more quickly and directly against a UK NGSO licensee (under the new licence condition) if there was harmful interference to GSO receivers in the UK.

NGSO systems sharing with terrestrial services

- A2.100 SpaceX said Ofcom should explore blanket licensing and unified light-licensing, which will enable even more efficient coordination and coexistence between satellite networks and terrestrial fixed services. In comments about access to E band it said that self-coordinated light licensing of satellite ground equipment was possible in higher frequencies because high-gain, directional beams create 'pencil beam' links that form small, predictable coordination zones between users.
- A2.101 BT said that in relation to future NGSO networks with very large numbers of satellites, (i.e. greater than 1,000), Ofcom should ensure appropriate PFD limits continued to be applied to avoid interference from satellites into terrestrial services, particularly 18 GHz fixed links.
- A2.102 OneWeb agreed that Ofcom should not act on interference resulting from the poor performance of receivers, and that it is the responsibility of the user to ensure receivers are effectively able to filter out signals from any neighbouring bands and emphasised this should apply equally to all users of spectrum.
- A2.103 However, it noted that placing high power terrestrial transmitters in bands adjacent to those used to receive weak signals from space could result in interference scenarios that may be difficult for receiver filtering to entirely address. It identified the potential role of NGSO satellites in disaster response and recovery as an example that needed consideration. It said any actions that would help should be considered as a priority in Ofcom's strategic approach to space spectrum.

Ofcom assessment

- A2.104 The sharing of spectrum wherever this is possible is a key part of Ofcom's overall spectrum strategy and is not limited to use of frequencies for the space industry. Sharing spectrum represents efficient use of a scarce resource for the overall benefit of consumers and businesses.
- A2.105 We will continue to engage in ITU work looking at the PFD limits to avoid interference from satellites into terrestrial services in 18 GHz (set out in RR 21.16.6). We note SpaceX's comments and will consider the appropriate approach to authorising earth stations in future consultations, including on E-band.
- A2.106 For avoidance of doubt our position, that it is the responsibility of the user to ensure receivers are effectively able to filter out signals from any neighbouring bands, is a general one relevant to all spectrum users, as set out in our overall Spectrum Management Strategy. Internationally, we will support work within ITU Working Party 4A to review recommendations on FSS protection criteria.

NGSO satellite downlinks sharing with Radio Astronomy

- A2.107 The Royal Astronomical Society said it noted that the impact of large satellite constellations on astronomy was significant in visible light and the near-infrared spectrum too, with limited mitigation and no formal international regulation. It said allocating further parts of the spectrum for commercial use impacts which areas of the spectrum can then be used for geophysics.
- A2.108 It said the scientific goals of radio astronomy depended on the use of the radio spectrum as a whole, not just its protected bands. Until now, sensitive equipment had been located away from other users. The advent of large NGSO constellations, with the specific goals of providing communications in remote areas, risked rendering these mitigations for interference redundant.
- A2.109 As a result, the Royal Astronomical Society said there was an urgent need to consider fuller geographical protections of key sites. It pointed out that satellite downlinks can be up to 10 trillion times as powerful as the signals detected from the faintest astronomical sources.
- A2.110 OneWeb said it supported the protection of radio astronomy. It said it worked closely with radio astronomers concerning the protection of sites and would be happy to work with Ofcom and the radio astronomy community to continue to identify flexible, dynamic ways to coexist.
- A2.111 SpaceX urged Ofcom to avoid imposing new licence conditions or prescriptive rules regarding coexistence between NGSO systems and radio astronomy, but instead to rely on the ITU Radio Regulations as a baseline. It said new rules were unwarranted.

Ofcom assessment

- A2.112 We recognise that faint signals from outer space can be susceptible to interference and that it is possible that large NGSO constellations visible to radio astronomy sites present an increased risk. We therefore agree it is important to ensure there are appropriate protections for radio astronomy from interference from NGSO (as well as GSO) downlinks in adjacent frequencies, and have set out our plans for future work to support this aim in section 4.

Space debris and space sustainability

- A2.113 Inmarsat, SES and Viasat all raised the issue of space debris. Inmarsat said it was a growing problem closely linked to the launch of NGSO mega constellations. It noted that the UK Space Agency and the CAA has primary responsibility in this area, but said it was important that the UK continued to apply conditions on space debris in its satellite licensing process. It added that operations outside the UK should meet the same requirements as UK licensed systems, to ensure a level playing field on space sustainability.
- A2.114 JRC said the big increase in the number of satellites in orbit is a concern which appears to be understood only partially at present. Further work into the potential for ever larger volumes of space debris should be undertaken because collisions had the potential to severely disrupt existing and new constellations.

- A2.115 Viasat said collisions in space could ultimately lead to a “belt of debris around the Earth,” leading to a series of self-sustaining collisions. This could make certain orbits unusable for critical civil, military and commercial space services.
- A2.116 SES said space objects and debris could impact the provision of existing space-based services (e.g. navigation, earth observation, weather monitoring and broadband). It therefore welcomed Ofcom's recognition of the importance of safe use/access to space and its intention to discuss this question with our counterparts in the CAA and the UK Space Agency.

Ofcom assessment

- A2.117 We recognise the growing interest in the issues of space debris and space sustainability. As noted by Inmarsat, these issues are chiefly the responsibility of the CAA and UK Space Agency¹¹. However, our role in spectrum management can also play a supporting part. The expanding number of NGSO constellations has created a need for more and better tracking of satellites and other objects in space, including deployment of more and higher performance radars.
- A2.118 We will consider appropriate access to spectrum for radars to track the movements of objects in space. We will continue to work with BEIS, UK Space Agency and CAA on this matter to understand if there is more that we can do to support UK objectives in this area, while acting in line with our duties.

¹¹ The UK regulator with responsibility for issues concerning the safety of space, including space launch and space debris, is the CAA as outlined in the Space Industry Act 2018. The UK's policy on safe and sustainable use of space is determined by UKSA and BEIS.

A3. Responses on other trends in the space sector

- A3.1 Although the growth of NGSO constellations represents the biggest recent trend in the space sector – and attracted the overwhelming majority of comments in responses to our March 2022 – respondents also identified some other trends.
- A3.2 In the consultation, we noted that the speeding up – and cost – of building, launching and maintaining satellites in space was not confined only to the NGSO satellites but applied across the sector. We said new satellites can be much smaller and weigh much less than their predecessors. At the same time, their overall capacity is increasing as new technology, often developed by the mobile industry, continues to improve.
- A3.3 Modern satellites are also able to offer greater flexibility across frequencies and service areas, while cloud services and artificial intelligence (AI) are improving network management. The March 2022 consultation said other trends in the space sector had implications for specific uses. We said:
- Satellites can contribute to improved communications services in the UK and globally;
 - There are increased needs related to climate and weather;
 - There is growth in general space activity, including around launches and space weather;
 - Satellite broadcasting is relatively stable but there is potential for market changes;
 - Emergency and disaster relief services remain vital.
- A3.4 We asked stakeholders the following question:

Question 1: Are there other trends in the space sector (or the broader spectrum environment) that we should monitor and/or take account of in our strategy?

Consultation responses

- A3.5 Most respondents agreed with our identification of the main trends in the space industry. A few respondents identified some specific additional trends in the development of services served by satellite.
- A3.6 By far the greatest volume of comment about trends in the space sector focused on the growth of NGSO systems – particularly the launch and operation of large constellations in low earth orbit (LEO). These comments have already been addressed above under “NGSO satellite communications”. Some respondents answered our question by discussing trends and issues of specific relevance to their own sectors of the space industry. We recognise that different stakeholders will have particular interest in how trends in the industry might affect them specifically, and some key points are discussed below. However, we note that

the main purpose of our space spectrum strategy is to provide an overall framework for spectrum management within which all sectors can thrive alongside each other. Particular issues that may be of more direct relevance for particular sectors will be addressed in more focused consultations in the future, as necessary and appropriate.

Lunar communications and space exploration

- A3.7 Some consultation respondents – notably the UK Space Agency/BEIS and Lockheed Martin – said Ofcom may have overlooked an important future trend: lunar/space exploration and its associated communications needs.
- A3.8 The UK Space Agency and BEIS said if the UK were to enjoy the potential benefits from such “inspirational activities” it was important that key foundations were set out now. Lunar and space exploration should therefore be a priority within our Space Spectrum Strategy. We consider these issues more fully in the next sub-section of this annex under “Our strategic objectives and priorities”.

Trends within particular services

- A3.9 We outline below some key developments within particular sectors or services identified by respondents. Most of them fall within the broad categories which we described in our March 2022 consultation and therefore will not affect the actions we proposed.

5G and 6G mobile

- A3.10 A number of respondents – including the Global Satellite Operators Association (GSOA), SES, Telesat, the UK Space Agency and BEIS and a respondent who wished their identity to remain confidential [REDACTED] identified the growing trend towards using satellite for 5G broadband services. GSOA and [REDACTED] said the spectrum needs of satellite for broadband was rarely acknowledged by regulators but it was the only way of delivering services to every part of the UK. It also reinforced service continuity. BT noted the growing importance of satellite for backhaul purposes.
- A3.11 SES said satellite systems are already an integral and essential part of the 5G ecosystem, able to actively contribute to the deployment of 5G services to end-users in the most remote geographical areas. They are enabling communications on the move, direct to premises, and connectivity in rural and urban areas. It said integration of NGSO and GSO systems was a trend already underway.
- A3.12 As 6G evolves in future, Telesat identified satellite as a means to “connect the unconnected” by enabling 5G and 6G delivery of Cloud services. But it said the more ubiquitous use of space services for mobile broadband meant the use of satellites was not going to be confined only to remote areas where terrestrial infrastructure is not yet deployed. It said satellite was enabling communications on the move, and for the energy and governmental sectors, in addition to commercial and private maritime and aeronautical applications.
- A3.13 GSOA said that, while it remains to be seen which 6G uses will become widely deployed, 6G will need to incorporate the full range of terrestrial and non-terrestrial technologies. As

all previous generations of wireless networks have demonstrated, the use of non-terrestrial technologies is essential for maximising coverage and bridging the digital divide.

A3.14 Not all responses were positive about delivery of 5G and 6G by satellite. [REDACTED]

Cloud services

A3.15 GSOA said another important evolution in the satellite sector is the association of the cloud with satellite. It said the March 2022 consultation had been confined to the improvements which cloud (and AI) bring to satellite network management. It pointed to how much cloud operators now count on satellite to extend their reach. It identified IBM, Microsoft Azure and Amazon as users of satellite to facilitate direct access to core and/or edge computing.

A3.16 SES also said an important evolution of the space sector is the way in which satellites and cloud services help each other to expand access and options for citizens. With the increasing rollout of digital transformation initiatives, cloud service providers such as Microsoft need to be able to process an increased amount of data at the edge of their network.

Earth stations in Motion (ESIM)

A3.17 GSOA noted the provision of high-speed broadband services to end users on the move was an important trend that should be recognised. SES said consumers and business travellers expect high speed broadband while traveling where terrestrial-only wireless and wired broadband networks cannot realistically deliver connectivity. ESIMs mounted on ships, aircraft, trains, and vehicles could fill in such gaps in terrestrial-only broadband networks.

A3.18 Telesat concurred, saying it said it was important for Ofcom to note that satellite communications services are not going to be confined only to remote areas where terrestrial infrastructure is not yet deployed. Satellite services were key to enabling communications on the move. There was an increasing demand from people to stay connected regardless of their location, and in places that are unreachable through terrestrial networks, including airplanes and vessels.

A3.19 SES said limits to FSS spectrum allocations hampered the ability of ESIMs to deliver the highest level of broadband service possible, or in some instances threatened the ability of satellite operators to deliver continuous ESIM coverage. It also commented that other CEPT countries make more spectrum available for the use by ESIMs or ESOMPs, in line with ECC decisions.

IoT services

A3.20 The growing importance of Internet of Things (IoT) services delivered by satellite was noted by Eutelsat, Kepler Communications, Kinéis and others.

A3.21 Eutelsat said demand for satellite based IoT, alongside the expected convergence of terrestrial and satellite networks, represented a distinct trend that should be recognised and considered.

- A3.22 Kepler Communications said satellite-based IoT was well-positioned to serve more remote applications such as long-distance asset tracking, maritime and other geographically isolated industry applications. IoT had already made a significant step away from merely connecting various electronic devices to now interconnecting almost “every object around us”.
- A3.23 Kinéis said IoT was “bridging the digital gap in isolated areas; complementing terrestrial connectivity; and ensuring continuity of cross-border services in various sectors (industrial, maritime, asset tracking, mining, etc.)”.
- A3.24 A respondent who wished its name to be withheld [REDACTED] also noted a “large trend” within the NGSO satellite sector on IoT. It said it would be beneficial both for the UK and the operators to establish rules and guidelines in order to provide possibilities for operators to get licences in appropriate frequency bands. It said increased spectrum requirements for both GSO and NGSO operations required all operators to respect a basic general partitioning of bands, accompanied by sharing conditions.

Real-time Earth exploration satellite data

- A3.25 Telesat highlighted a further trend in the space industry: demand for real time download of EESS data including high-resolution videos or photographs during exceptional circumstances (disasters, wars etc).
- A3.26 It said recent geopolitical events provided the necessary evidence to deem this application as strategic for UK citizens and consumers. In order to cope with the demand for high bandwidth and time sensitive data, it said operators were looking to employ inter-satellite links in the Ka-band or optical links in their satellite systems to transfer data between NGSO satellites and relay satellites that are then able to transmit the data to the required point in Earth.

In-orbit services

- A3.27 In general comments, Clear Space Today said the recent rapid growth of satellite services was driving a new nascent industry of in-orbit services. This included a range of activities including the transport and repair of spacecraft in orbit; the refuelling and life extension of spacecraft; and assisted disposal services, including the removal of debris.
- A3.28 Similar comments were made by GSOA, Confers and the UK Space In-Orbit Services and Manufacturing (IOSM) Working Group. GSOA said there were around one million space debris objects greater than 1 cm in size estimated in LEO orbits. It foresaw that dealing with this would be a major industry in the near future.
- A3.29 The IOSM Working Group said ensuring the safety and sustainability of space activities required the availability of scalable and prompt IOS solutions. This was an important and necessary component of enabling space activities.
- A3.30 Space Energy Initiative also invited Ofcom to “monitor and facilitate” access to spectrum for in-orbit servicing and assembly missions, including machine-to-machine communications. The UK Space Agency and BEIS said there was a need for an emphasis on

activity in space to be sustainable. This involved dealing with debris and preventing collisions.

Space weather

- A3.31 The Met Office identified the growing importance of space weather as a trend. It said an immediate priority work area should be the establishment of an international framework for space weather. It said vulnerability will continue to increase as our society becomes more reliant on systems which could be affected by space weather.
- A3.32 The UK Space Agency and BEIS also noted this issue. They said space weather (and off-earth spectrum) use will need international regulatory agreement to formalise the status of space weather sensors, as indicated in our March 2022 consultation.

Space based solar power

- A3.33 Space Energy Initiative urged Ofcom to take into account the development of space-based solar power (SBSP) technologies and their potential to deliver clean energy. It said Ofcom needed to consider the associated spectrum requirements of this nascent industry.
- A3.34 While the ITU and CEPT have developed several recommendations and guidance on the frequency ranges for the operation of non-beam and beam Wireless Power Transmission (WPT) systems for mobile and portable devices, Space Energy Initiative said additional applications such as SBSP systems require further work and guidance from spectrum management authorities.

Ofcom assessment

- A3.35 The trends identified by respondents have provided helpful further information on how the space sector is developing in particular areas within the scope of our space spectrum strategy. In many cases, we are already working to address issues raised by respondents. For example, to improve spectrum access for ESIMs and develop the international regulatory framework for space weather monitoring.

A4. Responses on our strategic objectives and priorities

- A4.1 The March 2020 consultation identified two overall **objectives** for our space spectrum strategy:
- To enable growth in the benefits that the space sector delivers for UK people and business.
 - To ensure efficient use of spectrum and create no undue constraints, with particular emphasis on **spectrum sharing**, in accordance with our broader [Spectrum Management Strategy](#). We said this would be achieved through the use of better data and more sophisticated analysis; the deployment of equipment that is more resilient to interference; and a good balance between protection given to one service and flexibility for others to transmit.
- A4.2 We identified three **priority areas** for action:
1. **Communications**: because it is going through significant change with major new entrants like NGSO constellations giving challenges for regulation and access.
 2. **Earth observation and navigation**: because it is vital to many different sectors e.g. agriculture, the emergency services, climate monitoring and weather forecasting.
 3. **Space access**: because of the need to access space safely and efficiently free from debris.
- A4.3 We said we did not intend to prioritise satellite **broadcasting** in this strategy, because we perceived there was no demand for additional spectrum.
- A4.4 We said we did not propose to focus on spectrum management changes for **emergency and disaster relief** because satellite systems providing these services already have the spectrum needed for their operation and we saw few regulatory changes needed at this time.
- A4.5 We asked the following question:

Question 2: Do you agree with the broad areas we have prioritised for our work?

Consultation responses

- A4.6 A large majority of respondents agreed with our main objectives and the three main priorities we proposed in the March 2022 consultation. As with answers to Question 1, some respondents elaborated on their answer by adding comments related to their specific sectors, but in most cases did not disagree with our overall priorities.
- A4.7 Stakeholders involved in broadcasting, or with particular interest in emergency and disaster relief, were anxious to ensure we understood the importance of their sectors, even if they recognised the reasons we gave for not making them a priority in our proposed space spectrum strategy.

A4.8 In the remainder of section A4 we first consider responses about our two objectives. We do this under headings related to factors we identified as contributing towards the efficient use of spectrum:

- spectrum sharing
- resilience of equipment
- the balance between protection and flexibility
- protection of satellite services

A4.9 We then go on to consider responses relating to our priority areas.

Comments on our objectives

A4.10 The UK Space Agency and BEIS said the objectives and prioritisation presented by Ofcom matched well with its own priorities, as expressed in the National Space Strategy. However, it said one area where the National Space Strategy and the Space Spectrum Strategy have a different perspective is around the timescales under consideration.

A4.11 It said the space sector is undergoing a rapid, transformative change. How quickly space systems can adapt to change presents a constraint to how quickly changes in spectrum use can be made.

A4.12 It said it was important to lay the foundations for future growth in good time, bearing in mind that updating international radio regulations can take many years. In practice this may mean that work towards enabling some of the longer-term elements of the UK vision will translate to more immediate priorities with respect to spectrum.

Spectrum sharing

A4.13 There was broad support for our overall aim to ensure efficient use of spectrum through sharing, although some respondents had specific comments relevant to certain circumstances.

A4.14 Kepler Communications said using technologies that allow for more efficient use of spectrum should be encouraged, rather than upholding a system that provides exclusive licensing. It added there should be wider use of dynamic spectrum access for NGSO satellites.

A4.15 Lockheed Martin urged Ofcom to “demonstrate global leadership” in driving equitable spectrum sharing requirements, particularly for technologies and services that have little natural incentive to share due to historic spectrum access models, such as exclusive licensing.

A4.16 Maxor and Aurora said frequency bands that are the most popular, and therefore contested today, clearly need to be used in the most effective manner and a time-based component to spectrum policy should be considered in addition to frequency, geography, and power levels. An expansion of more cost-effective spectrum monitoring from bespoke systems, RAN edge applications, and space-based RF mapping could be inputs to time-based spectrum sharing.

- A4.17 SpaceX said the development of more efficient sharing mechanisms between NGSO-GSO and NGSO-RAS/EESS, and NGSO-FS should replace overly conservative methodologies.

Resilience of equipment

- A4.18 OneWeb said it supported the position outlined within the objectives set out in the March 2022 consultation that we will not generally expect to act on interference resulting from the poor performance of receivers. It said it agreed it was the responsibility of the user to ensure receivers are effectively able to filter out signals from any neighbouring bands. However, it said the obligation should fall equally on all users of spectrum, and not disproportionately upon users of space spectrum.
- A4.19 On the other hand, Eutelsat said it was surprised that Ofcom did not generally expect to act on interference resulting from poor receiver performance. It said receivers can by nature only be victims of interference. It said the design and installation of very resilient equipment can result in significant costs.
- A4.20 Methera said adherence to equipment standards, and increasingly stringent design specifications (such as off-axis performance, cross-polar discrimination, and out-of-band rejection) was key to minimising NGSO to NGSO issues. Further, while the industry should always embrace new technology developments, it should be cautious about resulting compromises to performance.
- A4.21 Methera urged Ofcom to take an urgent and pro-active role to look at equipment performance standards associated with user terminals and gateways – and emphasised the importance of Ofcom considering not just LEO but also MEO and HEO as “a part of the NGSO catch-all”.

Balance of protection and flexibility

- A4.22 In respect to achieving our objectives by establishing the right balance between protection of existing services and creating flexibility for new operators, the UK Space Agency and BEIS urged caution. For example, they did not believe the UK spectrum regulator should seek to redefine internationally accepted limits on transmissions, which were often the result of delicate compromises. For the UK to apply its own, more relaxed protections would have a negative impact on our reputation and risk making reaching international agreement on future sharing much more difficult.
- A4.23 They also questioned our proposals to use measured performance of satellite equipment in preference to agreed international protection limits criteria, which are those applied within the ITU and other bodies to study and agree the criteria for sharing spectrum.
- A4.24 In general, the UK Space Agency and BEIS said space systems do not seek protection from emissions outside the bands where they operate, but do require protection from the unwanted emissions into the allocated band from services operating in adjacent bands. It said it agreed that the performance of transmitters, particularly their out of band emissions, was an issue and looked forward to improvements in this area.
- A4.25 Eutelsat commented on our overall objective of enabling growth in the space sector to deliver benefits for people and businesses in the UK, but expressed concern about our

focus on avoiding undue constraints to other users. It said reciprocity was also true, and other spectrum users should likewise avoid creating undue constraint on the development of the space and satellite industry.

Protection of satellite services

- A4.26 A respondent who wished its identity to remain confidential (XREDACTED) said our proposed strategy did not seem to include a general objective or policy statement to ensure that satellite services are protected adequately from interference from other spectrum users. It said such an assurance was needed.
- A4.27 GSOA said Ofcom needed to ensure that satellite services are able to do so on a long-term basis, without significant risk of interference from terrestrial or other satellite spectrum users. In the GSOA's view this should be a fundamental pillar of Ofcom's strategy, but one that seemed to be missing.
- A4.28 ManSat also raised this issue as an area for work. It said it would have expected an overarching objective of the strategy to be the adequate protection of satellite services from harmful interference by other users. It would like to see this explicitly stated as policy, rather than merely implied.

Ofcom assessment

- A4.29 Many of comments of respondents on sharing point to the importance of achieving the correct balance between flexibility to operate services and the protection of other services. In many cases, as noted by UK Space Agency and BEIS, this is guided by internationally agreed approaches. It is unlikely, for example, that any NGSO constellation interference issues will be a purely UK national matter.
- A4.30 However, there may be cases where we may consider a departure from international limits for UK services where we are able to show that real-life performance of equipment is better than those prescribed internationally and where international limits place an unnecessary limit on the deployment of other services.
- A4.31 Generally, as set out in our overall [spectrum strategy](#), we consider an approach based on actual performance of equipment is preferable to one based on historically established levels that may no longer be relevant.
- A4.32 As set out in our [Spectrum Management Strategy](#) the question of equipment standards is central to the efficient use of spectrum and sharing. All equipment should be designed to avoid interference to other users and to be as resilient as possible to interference from others. Equipment standards for Europe have generally been developed through the European Telecommunications Standards Institute (ETSI). We will continue to engage with ETSI on matters of importance for the use of spectrum. In seeking to ensure equipment is suitably resilient, we recognise that upgrading existing systems can take time - especially for equipment already in space - although this should not mean that upgrades are postponed indefinitely.
- A4.33 We note the comments of UK Space Agency and BEIS about the pace of change. We will continue to monitor technology and market developments to enable us to react in a timely

manner to further changes in the space industry. We agree there is a need to anticipate where there may be a future need to make adjustments to spectrum access frameworks.

- A4.34 We note the comments about the need for long-term assurance for satellite operators over interference. It was always our intention that such assurance would be part of our space spectrum strategy, provided satellites are appropriately resilient, since this is an important aspect of achieving the right balance between flexibility and protection.

Relative priority of broadcasting

- A4.35 Arqiva noted we had acknowledged "but not prioritised" the interests of broadcasting and media. It said it would be concerned if there was any lessening of the current support for this area as a consequence of the lack of a priority. It sought explicit protection of existing GSO services, such as those for satellite broadcasting, earth station uplinks and broadcast signals, to be addressed in the regulation and licensing of new developments.
- A4.36 The BBC commended Ofcom on its recognition of broadcasting as an important consideration for our space spectrum strategy. It said it did not necessarily call for broadcasting to be the same priority level as other sectors - but said it would be interested to know what evidence Ofcom has for saying there is currently no demand for additional spectrum for satellite broadcasting. It said successive WRCs have made decisions which have reduced access to C-band spectrum for broadcasting in favour of mobile and said there was a real possibility that this could happen again.
- A4.37 It urged action to protect its use of the 3.8–4.2 GHz band. It said this band was not just used for newsgathering. It was required for a significant amount of its distribution of international services (BBC World Service, BBC World News and BBC Studios) because it provides a reliable and effective way to provide services over large geographical areas. It is also essential for programme making (PMSE), sports coverage, and to enable the BBC to provide its open-source monitoring service.

Ofcom assessment

- A4.38 It is important to stress that our proposals to concentrate our space spectrum work on priority areas other than broadcasting do not in any way mean a diminution of Ofcom's commitment to the UK's broadcasting environment. Ofcom's 2022/23 [plan of work](#) sets out "supporting and developing UK media" as a continuing core priority.
- A4.39 Major broadcasters are key Ofcom stakeholders and we are in regular engagement on a wide variety of issues, including access to spectrum (such as for PMSE). However, we have not identified any aspects of space spectrum management that require priority attention.
- A4.40 We recognise the wide uses of spectrum by the industry, as identified by the BBC, and note concerns about the repurposing of bands (i.e. in C Band) to other services. We also note Arqiva's concerns about interference to GSO services and the potential link to our NGSO work.
- A4.41 In response, we can confirm that new users will only be licensed by Ofcom if their licence application is successfully coordinated. We have no current plans to change the protection criteria used to co-ordinate with existing services. Earth stations currently access the band

on a first come, first served basis and this will continue to be the case when new users gain access to the band.

- A4.42 Importantly, we have seen no evidence to change the view set out in our March 2022 consultation that *“whilst satellite broadcasting services deliver valuable TV content to UK consumers, there is currently no demand for additional spectrum for UK satellite broadcasting nor any significant changes in its spectrum use”*.

Relative priority of emergency and disaster relief

- A4.43 Access Partnership noted our identification of communications as a priority but said this overall area cannot be detached from other work areas. It said it wanted to highlight the increasing correlation of “communications” and “emergency and disaster relief” in coming up with a more robust space sector strategy. It expected to see the roll out of more agile, non-traditional tools that leverage satellite communications for emergency and disaster relief. As such, it might not necessarily be the case that satellite systems providing emergency and disaster relief services have the spectrum needed for their operation, as we had asserted in the March 2022 consultation.
- A4.44 Methera said it did not agree with our proposed priorities because emergency and disaster relief was not prioritised. It pointed to the Ukraine war as an example of how NGSO satellites can overcome a shortage of bandwidth in conventional GEO orbit. It urged us to reconsider our priorities.
- A4.45 GSOA also expressed concern about the lack of priority for emergency relief services. Even though there may be no or limited spectrum requirements it was important to ensure such operations can be provided wherever and whenever needed, without risk of interference.
- A4.46 Inmarsat said it agreed that systems for emergencies have adequate spectrum today, but that does not equate to no action being necessary. It said it was important that ongoing access to L-band — and parts of C-band, which is used by Inmarsat for feeder links — continued without interference. ManSat said that although emergency and disaster relief may have enough spectrum for now, they could still require action from Ofcom to ensure they are protected from harmful interference from other services. These services must have the ability to operate long-term with the certainty.
- A4.47 OneWeb said a key capability of NGSO communication systems was for disaster responses and recovery, given their ability to provide rapid connectivity at short notice to areas where communications infrastructure has been lost. Any actions identified that would help facilitate NGSO's critical role in global disaster response and recovery should be considered as a priority in Ofcom's strategic approach to space spectrum.
- A4.48 There was also support for prioritising disaster and emergency relief from SES, Space X, Met Office and others.

Ofcom assessment

- A4.49 As with the comments above in respect to broadcasting, it is important to stress that our assessment that we would not classify spectrum for emergency and disaster relief as a

priority space spectrum work area does not mean it is not of vital importance. Rather, it reflects our assessment that other aspects of space spectrum management will require more Ofcom review and efforts to update the regulatory framework in the next few years.

- A4.50 As almost all respondents acknowledge, there is currently sufficient spectrum for emergency and disaster relief, with no pressing need for further intervention.
- A4.51 We recognise the potential for more general satellite broadband communication systems (including NGSO systems) to play a part in disaster situations. While this may not be their primary purpose, our identification of satellite communications as a priority area will align with related needs of emergency and disaster relief agencies. Similarly, the assurance of spectrum access without undue interference is part of our on-going role in space spectrum management, including for emergency and disaster relief.

Lunar communications and space exploration

- A4.52 The UK Space Agency and BEIS said the expected growth in lunar missions will require greatly expanded communications capacity back to earth. They said that facilitating growth and innovation in "New Space" activities and supporting the space science and exploration goals, as outlined in the National Space Strategy, should be highlighted by Ofcom as a priority.
- A4.53 In their joint response, UK Space Agency and BEIS said both space weather and off-earth spectrum use will need international regulatory agreement to formalise the status of space weather sensors and to coordinate how spectrum is used around the Moon and Mars. They noted the UK's commitment to working with others on revisiting the Moon and said spectrum needs would have to be considered. They added that what might not appear as an immediate priority, should be treated as such if the UK is to benefit from growth in new space markets that do not yet exist, or participate in what they described as "inspirational activities" in space science, space travel and revisiting the Moon.
- A4.54 They noted that the UK had signed up to the Artemis accords to facilitate human activity on the Moon and Mars in 2020, and said there will need to be international regulatory agreement to coordinate how spectrum is used around the Moon and Mars.
- A4.55 Lockheed Martin said Ofcom needed to broaden its focus to include an understanding of the spectrum and associated regulatory requirements for lunar exploration and development, which is a trend of the future. Spectrum would be needed for lunar communications, navigation and infrastructure. In its view, these issues needed to be addressed internationally through the development of an international framework to ensure security of title and operations, consistent with both the Outer Space Treaty and the Artemis Accord principles, as referenced in the consultation.
- A4.56 With respect to the lunar economy, Lockheed Martin said it believed there are steps that need to begin immediately to ensure that the appropriate frameworks are in development and in place over the next few years.
- A4.57 ManSat also said Ofcom should monitor the increasing commercial activity in lunar and deep space missions in addition to the other space services mentioned in the March 2022

consultation. It said space missions were no longer the sole domain of agencies like NASA and ESA but were increasingly commercial too.

- A4.58 Northumbria University said we should focus on exploration and use of spectrum for astronomers and other actors in space plus future space missions such as to cis-lunar, lunar, and Mars locations.

Ofcom assessment

- A4.59 We recognise that lunar communications and space exploration are an important growth area for science and technology.
- A4.60 We have also taken account of the [National Space Strategy](#), including the Government's commitment to ensuring the UK takes a leading role in future exploration of space, and of the Moon and Mars in particular. The national strategy states: *"The UK reaffirms our support for activities to develop the Lunar Gateway and send astronauts back to the Moon over the coming decade. However, these activities are necessarily a part of wider international programmes (e.g. NASA Artemis mission to the Moon)"*.
- A4.61 Spectrum has an important role to play in enabling innovation in these areas. At present, it is unclear what the precise spectrum implications might be, at national or international level. We will continue to work closely with UK Space Agency and other agencies to better understand the potential spectrum requirements associated with lunar communications and space exploration.

MSS and Internet of Things (IoT)

- A4.62 Kinéis said priorities should include narrow band communication such as the MSS space IoT and EESS data collection platforms, which it said optimise the use of spectrum and answer unique needs which cannot be covered through other technologies.
- A4.63 Kepler added that active efforts to develop MSS technologies to bridge the gap between space and terrestrial mobile services were important. Accordingly, it did not agree that ITU agenda item 1.18 was a low priority. It said the agenda item could bolster the growth of IoT by enabling MSS operators to provide the necessary services, including improved global coverage without the need to hop between bands.
- A4.64 Myriota highlighted international inconsistencies in the licensing of VHF MSS spectrum. It said both VHF and UHF MSS frequency bands are already licensable in many other countries outside of Europe, including the USA, Canada, and Australia. Enabling licensing of the UHF MSS spectrum in the UK will be consistent with international regulations, and will achieve harmonisation with CEPT and various national spectrum regulators around the world.

Ofcom assessment

- A4.65 We agree there may be some benefits from IoT services provided under MSS allocations. However, international agreement is needed if additional bands are to be identified. As there has been no consensus on MSS system characteristics under preparatory work on

WRC-23 agenda item 1.18, ITU-R studies have not completed in time for there to be agreement at WRC-23 on potential allocations.

- A4.66 The frequency bands 137-138 MHz (space to Earth) and 149-150 MHz (Earth to space) are already authorised for MSS system in the UK. We will consider extending our national authorisation to cover other VHF/UHF frequencies, taking account of coexistence with other users and the demand for spectrum for IoT and M2M applications in the UK.

A5. Responses on work areas and actions: beyond NGSO specific issues

A5.1 For each of the three areas identified as a priority in the March 2022 consultation (communications, earth observation, and space access) we set out some specific actions we proposed to take. For each, we presented a table summarising our proposals and invited stakeholders to submit their views and comments. We also presented a table setting out proposed cross-cutting actions. These tables are replicated below.

1. Communications:

Issue	Action
<i>Spectrum access</i>	
Access to the 14.25-14.50 GHz band	We are examining options for the future use of the 14.25 – 14.50 GHz band and expect to consult on our proposals in Spring 2022.
Gateway earth stations in Q / V bands and higher frequencies	Develop our approach to licensing gateway earth stations in Q / V bands and higher frequencies.
Additional capacity for ESIMs (including those on aircraft and ships)	14.25 – 14.50 GHz - Consider use by ship and aircraft earth stations as part of our consultation on future use of that band.
	27.5 – 30 GHz: Consider updating the earth station network licence to allow use of wider bands, including conditions to protect users of the Spectrum Access licences.
	Monitor and appropriately engage with work on the WRC-23 agenda item studying ESIM in 12.75 – 13.25 GHz with a view to ensuring existing services are adequately protected.
Communications directly to/from 'normal' mobile handsets	Monitor developments in this area, including ability to share spectrum and demand for services in the UK.
<i>Efficient use, sharing and assurance</i>	
Protection criteria for FSS	Support work in ITU Working Party 4A to review recommendations on FSS protection criteria.

2. Earth observation

Issue	Actions
<i>Spectrum access</i>	
Protection of downlink sites for Earth observation data	26 GHz: Considering extending RSA to 26.5-27 if evidence of demand, whilst taking account of MoD use and future 5G authorisations.
	8 MHz: Consider evidence of future demand for 8 GHz ROES sites across the UK and whether any additional protections needed in light of growing fixed link use.
Inter-satellite links	Engage in international work under WRC-23 Agenda Item 1.17.
Climate change monitoring and weather forecasting capabilities	Engage in international work under WRC-23 Agenda Items 1.12 and 1.14.
Spectrum requirements to support resilient positioning, navigation and timing	Provide support as appropriate for the UK's satellite based PNT Programme.
<i>Efficient use, sharing and assurance</i>	
Ongoing protection of spectrum used for measurements	Consider Earth observation uses of spectrum when introducing new services and engage internationally to promote a balanced approach.
ITU Recommendation dealing with EESS sensors	Propose updates to the recommendation, including that it captures information on the selectivity of receivers.
Efficient use of S-band for TT&C	Engage in ITU-R work to develop a new Recommendation on the optimal use of S-band for TT&C.
Resilience of existing positioning, navigation and timing systems	We encourage manufacturers to use more robust GNSS receivers where available and will monitor developments of standards for PNT services.

3. Space access

Issue	Actions
<i>Spectrum access</i>	
International regulatory framework for space weather	Lead development of CEPT policy for WRC-23 agenda item 9.1.A.
Spectrum authorisations for UK space launch	Information is already available on our website. We encourage all operators to engage with us early on such authorisations.
Sub-orbital vehicles	Support efforts to create an international framework under Agenda Item 1.6 at WRC-23.
Safe use of space	Consider appropriate access to spectrum for radars to track the movements of objects in space.
	Seek to understand whether changes to international spectrum allocations are needed to support in-orbit servicing and other safe space initiatives.
<i>Efficient use, sharing and assurance</i>	
Protection of spectrum for radio astronomy measurements	In preparing to authorise access to the 26 GHz (24.25 – 27.5 GHz) band for future outdoor wireless broadband services we have made proposals for the appropriate protection of radio astronomy sites in the UK.
	Consider new licence conditions to ensure protection of radio astronomy (see section 6).
	Engage in CEPT and ITU work on development of appropriate solutions for protection of radio astronomy sites in the UK and abroad.

4. Cross-cutting actions:

Issue	Action
Supporting wireless innovation: spectrum for space pioneers	Identify a number of frequency and authorisation options that may be relevant for new cubesat/small sat applications.
Promoting spectrum sharing: Greater use of network licences	Consider greater use of network licences in the space sector, including the possibility of removing existing exemptions and transitioning to network licences.
Promoting spectrum sharing: Conditions on satellite downlinks	Consider, where relevant and appropriate, additional conditions on UK authorised equipment.

A5.2 In the March 2022 consultation we asked three related questions:

Question 3: Are there other issues and actions that are likely to be important over the next 2 – 4 years?

Question 4: Do you have any evidence on whether specific actions should be a high priority?

Question 5: Do you have any other issues you wish to comment on?

Consultation responses

- A5.3 As with answers to other questions, a majority of respondents supported our identification of issues and actions, or offered no comment.
- A5.4 Some stakeholders elaborated on why they supported our proposed actions in some areas, often with reference to issues of particular interest for their own sectors. Many stakeholders repeated or expanded on points they had already made in response to our questions on the objectives and priorities for our space spectrum strategy, or elsewhere within their submissions.
- A5.5 Some respondents made suggestions for additional actions they said should be prioritised, or identified further or different work in areas we had already planned to prioritise. We identify these in the sub-sections below.
- A5.6 In response to Question 4 about evidence for specific actions being high priority, respondents generally endorsed the arguments we had already set out in our March 2022 consultation or repeated or expanded on arguments they made elsewhere in their submissions.
- A5.7 A common theme in responses to all our questions was the desire for access to additional spectrum for particular sectors of the space industry. Comments centred on full access to

Ku and Ka band spectrum (including guard bands in the Ka band 28 GHz frequencies); access to Q/V spectrum; and E band spectrum.

- A5.8 We have taken account of all consultation responses in setting out which bands we intend to prioritise for access (see section 4 of the main part of this statement headed Implementing the Space Spectrum Strategy).
- A5.9 It is important to note that the purpose of our strategy is to establish an overall framework for our work over the next few years; within this we will develop specific proposals and consult where needed.

Comments on actions for communications

Access to spectrum generally

- A5.10 Among the respondents raising the issue of greater access to spectrum for satellite communications were Eutelsat, GSOA, SpaceX, tech UK, Telesat, Viasat, Myriota, OneWeb, SES and others. In almost all cases, the frequencies they identify had already formed part of our considerations in the March 2022 consultation. We do not summarise all comments below, but focus on responses raising additional points to those set out in the March 2022 consultation.
- A5.11 Many of the points made by stakeholders focussed on access to additional spectrum for NGSO satellite use. They are addressed here because the spectrum may also be used for GSO satellite purposes. In granting any additional spectrum access we will generally seek to enable access for both NGSO and GSO systems where possible.

Full access to both Ku and Ka bands

- A5.12 SpaceX said Ofcom should prioritise full access to the Ku and Ka bands for NGSO systems to minimise the risk that consumers will be left without adequate connectivity. Without access, it said, satellite operators would be constrained in their ability to connect consumers across the United Kingdom and to respond to unforeseen spikes in demand due to natural disasters and other crises.
- A5.13 Moreover, it said, a lack of access to sufficient spectrum would leave more operators sharing increasingly congested bands, making it more difficult for satellite operators to compete alongside terrestrial operators with greater access to spectrum.
- A5.14 OneWeb said the current UK requirement for satellite user terminals to coordinate with a limited number of fixed service links in the 14.25-14.5 GHz band placed a significant constraint on the provision of domestic satellite services. It said this was not the case in most other European countries.
- A5.15 It said the time frames associated with site-by-site coordination "simply do not work well in deploying a service to customers". As a result, it said, most satellite operators focus their offerings in the UK on the 14.0–14.25 GHz band. This results in congestion that prevents the optimal deployment of satellite services in the UK. To maximise the provision of

connectivity across the country, the deployment of satellite user terminals for the whole 14.0-14.5 GHz should be on an uncoordinated and ubiquitous basis.

Access to 28 GHz awarded bands (Ka band)

- A5.16 SpaceX said (in response to question 3) the 28 GHz band should be a particular priority for our space spectrum strategy. It said specific intervention was needed by Ofcom to enable easy access. It noted that the band has been allocated on a co-primary basis for fixed-satellite services and said it was essential to enable satellite operators to meet the growing demand of consumers for spectrum access. However, satellite operators lack full access to this critical spectrum in the United Kingdom because part of the band has been exclusively assigned to three terrestrial operators.
- A5.17 As a result, Space X said, satellite operators are required to negotiate for leased access to this spectrum. However, they said that with no obligation on licensees to negotiate in good faith, or to share the spectrum on a co-equal basis, terrestrial operators sought rents costing hundreds of thousands or millions of pounds per year. They argued that this arrangement for 28 GHz spectrum harms satellite consumers and competition.
- A5.18 Amazon also urged Ofcom to open up more of the Ka band frequencies for NGSO uplink operations – in particular the 28 GHz band - without the necessity for operators to obtain permission from existing licensees.

28 GHz guard bands

- A5.19 Amazon noted there were four guard bands in the Ka-band, between 28 GHz and 29.5 GHz, which were not currently authorised for satellite use.
- A5.20 It said modern satellite systems are using - or plan to use - the Ka-band for gateways and/or earth station terminals. Making the guard bands available would increase the capacity available to such systems and provide for greater flexibility.
- A5.21 The question of access to the 28 GHz guard bands was also raised in the context of NGSO services, with Viasat, Eutelsat and Telesat all noting the benefits that they considered access to those bands would bring.
- A5.22 Viasat said today's satellite modems are capable of producing sharp filter roll-offs, and that with earth station antenna off-axis gain reduction and selectivity of the adjacent band receive filter, adjacent band interference can be managed adequately without the need for guard bands. Telesat also indicated a view that there is no technical reason to maintain any guard band in this case.

NGSO systems to access the same spectrum as GSO systems

- A5.23 OneWeb said it agreed with Ofcom's proposal to consider providing NGSO systems with access to the same spectrum as GSO systems. Specifically, it supported amendments to the Earth station network licence to enable NGSO ship/aircraft earth stations to use the same parts of Ku and Ka band spectrum that are currently available for GSO use (as well as the corresponding changes to the Ship and Aircraft Radio licenses themselves).

A5.24 This view was supported by techUK and Telesat. Telesat said there was no substantive difference between NGSO and GSO in terms of coexistence with other services. Kepler Communications also agreed with our proposals to extend earth station network licenses for Ku-band NGSO systems for ESIMs

Q/V bands

- A5.25 In relation to NGSO systems, there was support for opening up Q/V bands for earth station gateways from OneWeb, Telesat, Amazon.
- A5.26 OneWeb said any new approach to licensing Q/V bands will need to ensure that satellite earth stations are adequately protected from any 5G terrestrial mobile service bands that may overlap. This position was also supported by Telesat, who sought clarification over whether both NGSO user terminals and gateways could access the Q/V bands. In any case, Telesat said it encouraged Ofcom to consider developing an approach in Q/V bands in accordance with ECC/DEC/ (21)01.
- A5.27 Amazon also said it supported our proposals to incorporate the FSS Q/V band into the licensing regime for NGSO systems, and for such licences to be available in the near term. It said any resulting sharing environments with terrestrial services should be based on spectral efficiency for both.
- A5.28 In addition to respondents raising access to Q/V bands specifically in the context of NGSO systems, a number of other respondents highlighted the importance of access to Q/V bands
- A5.29 GSOA and tech UK both said these frequency bands will play a vital role in enabling feeder links for the next generation of high throughput satellite systems. GSOA said additionally that Q/V bands were particularly suitable due to their sizeable contiguous spectrum and the opportunity to further augment wide bandwidth. GSOA added that use of Q/V bands will also be fuelled by the rapidly falling costs of components, making satellite systems that operate in these bands more affordable.
- A5.30 SES said the Q/V bands are well suited for feeder links for the next generation of high throughput satellite systems due to their sizeable contiguous spectrum and the opportunity to further augment wide bandwidth in case of Ka-band shortage. Inmarsat said it was pioneering the use of Q/V band for gateway stations and so supported our proposals.
- A5.31 Eutelsat and Amazon raised the possibility of space use of frequencies within the Q/V that we had not identified in the March 2022 consultation – 51.4-52.4 GHz. Amazon said it supported further ITU studies to evaluate use of these frequencies by NGSO systems, in addition to current use by GSO systems.
- A5.32 Eutelsat noted that ITU WRC-19 had identified 51.4-52.4 GHz as a new allocation for Fixed Satellite Services (Earth-to-space), and invited Ofcom to consider adding the band into the Frequency Allocation Table (FAT).

E band

A5.33 Space X said there is a high, immediate demand for E-band spectrum within the satellite community. SpaceX's second-generation constellation will use spectrum in the E-band for gateway earth stations to meet the growing demand of consumers for next-generation satellite services. It said Ofcom should further modernise its policies for high-frequency spectrum management by extending the existing self-coordinated light-licensing model for fixed links in the E-band to the entire 71-76 GHz/81-86 GHz range, and accommodate fixed-satellite service gateways.

Ofcom assessment

A5.34 Our March 2022 consultation proposed actions to explore opening up the Ku and Ka bands to wider satellite access, and to develop an approach to licensing gateway earth stations in the Q/V bands and higher bands such as E band.

A5.35 We note that comments about opening access for NGSO system operators to GSO frequencies in the Ku and Ka bands are in line with our own position as set out in the March 2022 consultation. In regard to responses linked to updates to the Earth Station Network licence, we have now published a [decision](#) to extend access in the Ku band 14.25-14.50 GHz frequencies.

A5.36 We will consider additional changes to the Earth Station Network Licence focusing initially on authorisations for NGSO maritime services and then, after WRC-23 on NGSO aeronautical services. We note the request to include Q/V band for terminals. However, we assess that the technology is still somewhat immature so this is not a priority for us at this time.

A5.37 Regarding access to 28 GHz awarded bands¹², the current licences allow the licensees to use the band for satellite gateways, or to trade or lease access to satellite operators if they wish. We note that satellite operators can (and do) gain access through commercial arrangements with the existing licensees. We will continue to monitor developments in demand and supply of 28 GHz spectrum for the sector and welcome further feedback from stakeholders on this matter.

A5.38 We will consider providing access to the guard bands in the Ka-band, although this may be dependent on stakeholders securing commercial arrangements with 28 GHz licence holders in adjacent frequencies.

A5.39 We welcome the additional evidence regarding the importance of Q/V band and E-band for feeder links. We note that terrestrial services are also interested in both bands and will therefore examine the options for sharing. There are already sharing conditions in place in the Q/V bands, but we need to examine options for E-band in more detail.

¹² Awarded bands are 27.8285 – 28.0525 GHz paired with 28.8365 – 29.0605 GHz; 28.0525 – 28.1645 GHz paired with 29.0605 – 29.1725 GHz; 28.1925 – 28.3045 GHz paired with 29.2005 – 29.3125 GHz and 28.3325 – 28.4445 GHz paired with 29.3405 – 29.4525 GHz.

- A5.40 On the 51.4-52.4 GHz frequencies, we will consider the case for including the new FSS allocation into our FAT and in future consultations regarding satellite access to Q/V bands.

Licensing of MSS NGSO communication systems below 1 GHz

- A5.41 Some stakeholders disagreed with our proposal to consider moving the licensing of MSS NGSO communications systems below 1 GHz from being licence exempt to a light licensing regime.
- A5.42 Inmarsat said it accepted that network licences may be applied in more cases in the future. Nonetheless, the current regime based on licence exemption seems to have functioned well for many years.
- A5.43 Stakeholders from the IoT sector were particularly keen to see easy access to spectrum. Lacuna Space was one of two stakeholders to propose particular approaches. It said licence-exempt bands have been established to provide easy access to users and have been the reason for significant advances in wireless technologies. Any changes in licensing should not result in disadvantages for the users. It said Ofcom should not be “reinventing systems”. Instead, we should simply ensure that when satellite operators use bands allocated for IoT/M2M applications they do not use them for other purposes (such as TT&C).
- A5.44 It added that receiving gateways on satellites should not be treated differently to terrestrial gateways because they were essentially the same. It therefore opposed individual licensing. However, it conceded there may be a case for an apparatus licence for transmitting IoT gateways on satellites.
- A5.45 Kinéis and CLS said their own operations presented a very low interference risk and suggested they should be exempt from individual licensing or subject to a light licensing regime. It said the space IoT business model relied on low-cost solutions. Myriota recommended that Ofcom's proposed implementation of light licensing avoids introducing additional burdens to operators of systems already approved by CEPT.

Ofcom assessment

- A5.46 As we noted in our March 2022 consultation, there is increased interest in spectrum access for MSS systems operating below 1GHz (VHF/UHF). This growth appears to be driven by the introduction of low-cost small satellite constellations to provide IoT/M2M services.
- A5.47 At present, MSS systems operating below 1 GHz are authorised on a licence exempt basis in the UK. We agree that licence exemption and light licensing provide easier access to spectrum than individual licensing. However, the expansion of services in these bands makes it important that spectrum is shared by operators so that as many services as possible can thrive, without risk of degradation.
- A5.48 We will therefore consider the potential transition from exemption to light licensing for bands used by MSS systems below 1 GHz. As noted in our March 2022 consultation we believe this could support greater spectrum sharing without introducing material new

barriers to spectrum access. We will separately consult on any proposed changes as appropriate.

Comments on actions for Earth observation and navigation

- A5.49 The Met Office had particular concerns for the protection of measurements underpinning climate change monitoring and weather forecasting. It said that, given the importance accorded to Earth observation in our proposed priorities, it was “surprising to see spectrum sharing also feature prominently.”
- A5.50 It said many of the instruments upon which it relied had minimal on-board RFI interference protection as they were designed and built with the expectation that the frequency bands they used would continue to benefit from high levels of protection for the decades of planned operation.
- A5.51 The Met Office said it supported the efficient use of spectrum and acknowledged there may be opportunities for additional Earth and space weather observations from NGSO satellites (e.g. exploiting the outcomes of the Space Weather Instrumentation, Measurement, Modelling and Risk Programmes).
- A5.52 However, this should be accompanied by scientific studies which demonstrated that it can be achieved without unacceptable consequences, especially for the bands used for passive remote sensing, which are highly sensitive to radio interference.
- A5.53 Maxar and Aurora concurred with the Met Office. They contended that the protection of incumbent users should be a priority in the next two to four years. Specifically, it said an action area should be to establish clear protection criteria. Legacy/incumbent EESS systems may have been designed and fielded many years before NGSO mega-constellations were even considered a possibility. They were not designed for resilience and coexistence with NGSO constellations.
- A5.54 Spirent said the UK's post-Brexit strategy on positioning, navigation and timing (PNT) required priority consideration by Ofcom. It said the UK needed to keep options open in terms of any emerging UK PNT programme – in its view enhanced UK capability in this area was likely to use a mix of technologies.

Ofcom assessment

- A5.55 As set out in our March 2022 consultation, we recognise the importance of accurate measurement to support weather forecasting and climate change. One of our priorities is the ongoing protection of spectrum used for Earth observation measurements.
- A5.56 However, if there is overly conservative protection of spectrum for a given user this can significantly constrain the development of other services. We will therefore continue to strike the optimal balance across the needs of Earth observation and the needs of communication services, by applying our principles for promoting spectrum sharing. These were set out in our spectrum management strategy and reiterated in our space spectrum strategy consultation.

- A5.57 We would also encourage EESS operators to take into account the increasingly congested nature of both space and spectrum when designing future satellites and sensors. This should increase the resilience of their measurements.
- A5.58 We note the comments of Spirent on PNT and will continue to monitor this area and potential spectrum implications.

Comments on actions for understanding and enabling access to space

In-orbit servicing

- A5.59 GSOA noted that Ofcom had submitted initial documents to CEPT on spectrum access for In-Orbit Servicing (IOS), but said "further timely pro-active action by Ofcom in this regard would be welcomed" to incentivise investment in this important area.
- A5.60 Clear Space Today and Confers also raised issues on IOS. They said effective licensing pathways to secure access to Telemetry, Tracking and Command (TT&C) frequencies are crucial for the development of the IOS industry. IOS missions have limited overall spectrum needs but require protected communications in critical phases such as proximity operations and capture.
- A5.61 They said the licensing process at the national level and the filing process at the ITU level should consider the peculiarity of IOS, with missions spanning various orbital regimes, having short periods with critical communications needs, and servicing different client objects.

Ofcom assessment

- A5.62 Access to reliable telemetry and command frequencies for IOS has traditionally been seen as challenging as it was assumed its use was limited to one specific international radio service allocation.
- A5.63 However, given recent clarifications by the ITU Radiocommunication Bureau (which aligns with our initial view), we do not currently see a need to propose changes to the international regulatory regime to facilitate TT&C operations for IOS, as these can be supported under existing international allocations. We will keep monitoring the evolution of IOS and evaluate whether other actions are needed.

Radio astronomy

- A5.64 STFC UKRI noted that radio astronomy was a passive activity, which is reliant on quiet skies to detect incredibly faint signals. Radio astronomy cannot move to use alternative frequencies, since the specific bands used are determined by physics. Further, it considered that moving UK-based facilities to other locations - other than where the science requires it - would jeopardise the UK's ability to provide valuable training and public engagement opportunities.

A5.65 STFC UKRI said that any assessment of new developments in the space sector should include consideration of the impact these might have on astrophysical research (from the UK but also internationally). If this were adversely affected by a degradation of the space environment this would be likely to have considerable negative impacts across education, culture and development for the UK.

Ofcom assessment

A5.66 As set out in above, we recognise the importance of radio astronomy and its reliance on ability to detect very faint signals. As part of our work programme we will consider the introduction of new licence conditions to provide us additional enforcement options in case of harmful interference to radio astronomy.

Safe use of space

A5.67 Spirent said Ofcom should work with other regulators (including Space regulators) to consider whether potential updates to international rules/processes are required to minimise the risks posed by satellite operations that do not adhere to the responsible use of space. This could include action to prohibit the launch of satellites without propulsion systems above a certain altitude.

A5.68 Good operational practices were also highlighted in OneWeb's response. Specifically, it said, operators should be able to identify their assets, have full awareness of where they are, and be in full control of their trajectories at all times. It suggested Ofcom work with other regulators to consider whether potential updates to international rules and processes were required. This could include prohibition of satellite launches without propulsion systems above a certain altitude and robust collision avoidance capabilities.

A5.69 Kepler Communications said global orbital tolerance was a high priority for NGSO operators. It said it was important that rules were not overly restrictive, given the reality of operating in Low Earth Orbit (LEO). It noted that many small NGSO satellites do not have propulsive orbit-raising capabilities and operate in an ever-decreasing altitude until disposal.

Ofcom assessment

A5.70 We note and acknowledge the issues raised by respondents, which were also raised under their comments on NGSO systems specifically (see 'space debris and space sustainability' above). In most cases, these issues are the responsibility of the CAA and/or through UN COPUOS and are not specifically related to Ofcom's spectrum responsibilities. However, we will continue to work with UKSA and other government bodies to better understand the linkages between spectrum and broader space sustainability and safety issues and where appropriate coordinate the UK approach in international forums on these issues.

A5.71 We have addressed the broad issues raised by Kepler Communications under NGSO-NGSO coexistence from paragraph A2.50.

Comments on work areas and actions for cross cutting areas

NGSO licence obligations

- A5.72 SpaceX said any proposals to add new conditions on satellite downlinks and on UK authorised ground equipment to address potential interference, for example to radio astronomy, were unwarranted and Ofcom should avoid adding them. It said that, as Ofcom has already adopted an entirely new and untested licensing regime which it said was “proving to be extremely complex and cumbersome” it would be premature to add conditions to address “a speculative issue”.
- A5.73 Inmarsat also said it was important that the scope of any licensing activity was limited to ensuring compliance with internationally agreed obligations. It added that it could not support any activity to introduce UK only limitations.

Ofcom assessment

- A5.74 We do not agree with the SpaceX assessment of licence conditions to protect radio astronomy. As noted in the March 2022 consultation, the downlink for some NGSO (as well as GSO) systems operate in frequencies which are adjacent to those allocated for radio astronomy use.
- A5.75 With the deployment of several large NGSO constellations, and due to the fact NGSO satellites are always in motion, we consider the likelihood of space to Earth interference caused by NGSO satellites above radio astronomy sites is considerably higher than for GSO satellites.
- A5.76 Therefore, as discussed in section 4, although we consider existing processes to be sufficient at present, we will also consider whether introducing new licence conditions to provide us with the ability to take more direct enforcement action, beyond reaching out to the administration responsible for the interference, in cases of harmful interference to radio astronomy. Given that some earth stations operating adjacent to radio astronomy are currently authorised via licence exemption, we will also consider transitioning them to network licences.

Compliance with equipment regulations

- A5.77 Methera noted that Ofcom referred to imposing additional conditions on UK authorised equipment and applauded this approach. However, it said there were already significant numbers of NGSO terminals in use globally which are understood to fail to meet the additional conditions deemed by Ofcom as necessary to impose. Ensuring this was addressed should be a priority.

Ofcom assessment

- A5.78 We note the point made by Methera. Whilst Ofcom has no legal authority to dictate how other jurisdictions address licensing conditions, we will continue to work with international bodies to influence appropriate approaches to coexistence issues on a global basis.

Spectrum for space pioneers

- A5.79 Northumbria University said missions are already in the planning phase for the Moon and Mars and, since regulations typically tried to catch up with science and technology, it was a good idea to start consideration sooner rather than later. Supporting wireless Innovation and spectrum for space pioneers could therefore be considered for high priority. It would boost entrants to the space market and support smaller business and academia where more support may be required. It would also help to promote international ideas of access to space for all.
- A5.80 ManSat said there should be a separate spectrum access regime for space pioneers that reflected their ability to progress from concept to launch on timescales of several months as opposed to many years.

Ofcom assessment

- A5.81 In line with the comments of Northumbria University and the approach proposed in the March 2022 consultation we plan to provide further information about the process for applying for [spectrum](#) authorisations for pioneering space work. Where possible we will endeavour to streamline our processes for assessing and granting such licences.
- A5.82 We note that some satellite operators may be able to launch satellites and commence service quicker than others. However, international processes for the coordination of satellite networks must be adhered to, to ensure these can operate without harmful interference. We urge satellite operators to submit their satellite filings as early as possible to avoid any regulatory delays.

A6. Other issues raised by stakeholders

A6.1 A number of other issues were raised by stakeholders in their responses to our March 2022 consultation. We have taken account of all comments received when finalising the space spectrum strategy statement. We summarise some of the other issues raised below.

Space energy

A6.2 Space Energy Initiative said it was important to work now on securing access to spectrum for services looking to collect solar energy in space and transmit this to Earth. It said identification of appropriate frequency bands in the next two to four years will be a crucial milestone to enable and secure such a concept in time to meet sustainable energy goals.

A6.3 It urged us to include in the Space Spectrum Strategy an additional action aiming *“to understand what (if any) changes to radio regulations and international spectrum allocations and spectrum coexistence arrangements are needed to support applications of wireless power transmission via radio frequency beam in space and from space to earth”*. In its view development needs to commence with urgency and with the right scale of funding.

Ofcom assessment

A6.4 We note this interesting development in energy generation in space. Several frequency bands are already agreed, internationally, for Industrial, Scientific and Medical (ISM)¹³ use, where this designation is provided for the use of spectrum for non-communication applications. As there are a number of specific policy and regulatory issues to consider here, a number of which fall outside the statutory duties of Ofcom, we are still considering the appropriate way forward in respect to this innovative technology.

Electro-sensitivity

A6.5 In its response to our consultation question on trends (and also in its response to other questions) Electrosensitivity UK identified a trend towards increased amounts of radio frequency radiation (RFR) from man-made use of spectrum, including from the space sector. It said this presented a risk to human and other life, particularly to insect life.

A6.6 Electrosensitivity UK said Ofcom's space spectrum strategy should include an assessment of the total amount of RFR emitted from space in addition to terrestrial sources. It said Ofcom should ensure that this total and cumulative RFR complies with international scientific RFR guidelines – but urged Ofcom to reject the guidance of the International Commission for Non-Ionizing Radiation Protection (ICNIRP).

¹³ https://www.ofcom.org.uk/__data/assets/pdf_file/0022/103297/fat-ism-frequencies.pdf

Ofcom assessment

- A6.7 Ofcom has statutory responsibility for managing radio spectrum in the UK. However, Ofcom is not a public health body and does not have medical or health expertise to make the kind of assessments being urged by Electrosensitivity UK.
- A6.8 The UK Health Security Agency, established in April 2021, now has overall statutory responsibility for public health issues. It continues to support advice on EMF exposure developed previously by Public Health England (and adopted by public health bodies in Scotland, Wales and Northern Ireland). The main advice of the guidance is that EMF exposure should comply with guidelines set out by the International Commission on Non-ionizing Radiation Protection (ICNIRP).
- A6.9 It is entirely appropriate for us to follow PHE's advice in making our proposals on EMF exposure. It is not appropriate for us to assume responsibilities beyond our own statutory duties, especially where doing so impinges on – and would undermine – the duties conferred by Government on another body.
- A6.10 In October 2020 we published a [decision](#) to include a specific condition in Wireless Telegraphy Act licences requiring licensees to comply with the ICNIRP general public limits on EMF exposure. We apply a similar approach for equipment that is exempt from the requirement to have a licence and that is authorised to transmit at powers higher than 10 Watts EIRP, such as certain types of satellite terminals. We now require spectrum licensees to keep records to demonstrate how they have complied with the ICNIRP general public limits.

A7. Glossary

3GPP	The 3 rd Generation Partnership Project, comprising of a number of standards organisations which develop protocols for mobile telecommunications.
AI	Artificial intelligence.
Backhaul	In a satellite context, this is a service provided to broadband and mobile telecommunications companies, helping them to extend their networks into hard to reach areas.
CAA	The Civil Aviation Authority
CEPT	European Conference of Postal and Telecommunications Administrations.
Cloud services	Refers to a wide range of services delivered on demand to companies and customers over the internet.
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
Downlink	Space to Earth communication going from a satellite down to a ground (or air or sea) based earth station.
Earth station	A station located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for radio communication with one or more satellites or space stations.
EESS	Earth Exploration Satellite Service. A satellite radiocommunication service which obtains information relating to the characteristics of the Earth and its natural phenomena from active or passive sensors on the satellite, and distributes this information to earth stations.
EPFD	Equivalent Power Flux Density – an algorithm designed to measure interference from satellite systems.
ESA	European Space Agency.
ESIM	Earth station in motion (also see ESOMP). ESIM provide satellite connectivity to moving platforms, including located on ships, aircraft and vehicles.
ESOMP	Earth stations on mobile platform. A satellite earth station mounted on a mobile platform such as an aircraft, ship, train or road vehicle, intended for communication with one or more satellites.
EUMETSAT	European organisation for the Exploitation of Meteorological Satellites.
Fixed links	Fixed links or fixed wireless access (FWA) are terrestrial based wireless systems, operating between two or more fixed points. Using mainly digital technologies, directional antennas and typically operating at very high

	levels of propagation availability fixed terrestrial links are used to provide network infrastructure and customer access applications across a wide range of frequency bands.
Frequency band	A defined range of frequencies that may be allocated for a particular radio service, or shared between radio services.
FSS	Fixed satellite service. Two-way communication links between earth stations, usually at fixed locations, and one or more satellites.
Gateway	These are large hubs that connect the satellite network to the internet and/or to private networks and cloud services.
GHz	Gigahertz. A unit of frequency of one billion cycles per second.
GNSS	Global navigation satellite system (examples include GPS or Galileo).
GPS	Global Positioning System. A space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
GSO	Geostationary satellite orbit. The orbit of a satellite whose circular and direct orbit lies in the plane of the Earth's equator and which remains fixed relative to the Earth's surface.
HAPS	High altitude platforms are vehicles - for example manned or unmanned aeroplanes, balloons, or airships - situated in the stratosphere used for the delivery of wireless communications.
In-orbit services	Refers to the provision of support services by a spacecraft (servicer) to another space object (serviced) while in orbit. For example, removing broken satellites from orbit and addressing the problem of space debris.
Inter-satellite links	Inter-satellite links are used to transfer data between earth observation satellites and relay satellites that are then able to transmit the data to the required point on Earth.
IoT	Internet of things.
ITU	International Telecommunications Union - part of the United Nations with a membership of 193 countries and over 700 private sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland.
ITU-R	International Telecommunications Union Radiocommunication Sector.
Ka band	Spectrum frequencies commonly in the ranges around 30 GHz (Earth-to-space) and 18 GHz (space-to-Earth).
Ku band	Spectrum frequencies commonly in the ranges around 14 GHz (Earth-to-space) and 11 GHz (space-to-Earth).

LEO	Low Earth orbit. LEO satellites orbit the earth at heights between typically a few hundred kilometres to one or two thousand kilometres above the earth's surface.
M2M	Machine to machine refers to technologies that allow both wireless and wired systems to communicate with other devices of the same type. M2M is a broad term as it does not pinpoint specific wireless or wired networking.
Mbps	Megabits per second.
MEO	Medium earth orbit. MEO satellites orbit the earth at heights of around 10,000 km above the Earth's surface.
MHz	Megahertz. A unit of frequency of one million cycles per second.
MSS	Mobile satellite service. Two-way communication links between portable user terminals and one or more satellites.
NGSO	Non-geostationary satellite orbit.
Q/V bands	Spectrum frequencies between 33 – 75 GHz are commonly known as Q/V bands. Q band ranges from 37.5 to 43.5 GHz, V band ranges from 47.2 – 50.2 GHz and 50.4 – 51.4 GHz are used for satellite.
Radioastronomy	A branch of astronomy concerned with radio emissions from celestial objects.
Radio Spectrum	The portion of the electromagnetic spectrum below 3000 GHz used for radiocommunications.
RAS	Radio astronomy service. The ground based reception of naturally occurring emissions in order to research astrophysics and cosmology. This service is typically used in the study of celestial bodies such as pulsars, the formation of new stars, the properties of interstellar gases and plasmas, solar activity and microwave background radiation, the study of invisible mass and energy, and the expansion of the Universe.
ROES	Receive-only Earth Station. A satellite earth station which receives radio signals but does not transmit.
RR	Radio Regulations.
RSA	Recognised Spectrum Access.
Satellite filing	A satellite filing is not a licence, rather the process of obtaining internationally recognised spectrum and orbital resources prior to the deployment of a planned satellite network / system.
S-band	Spectrum frequencies commonly in the ranges around 2 GHz (space-to-Earth and Earth-to-space).

SKA	Square Kilometre Array. An international project to build the world's most powerful radio astronomy sites, located in Australia and South Africa, with its headquarters based at Jodrell Bank observatory in the UK.
Smallsats / cubesats	Smallsats and cubesats are both types of satellites of small size and low weight.
Software-defined satellites	A telecommunications satellite that can be reprogrammed in-orbit. Satellite operators can reshape radio beams or resources of the satellite in almost real-time to meet the changing demands for data transmissions.
Sub-orbital vehicles	These are flights to the edge of space (~100km) lasting a few minutes.
SVOD	Subscription video on demand.
Transportable Earth Station	A Transportable Earth station (TES) is a satellite earth station operating from a specified location to a satellite in the fixed satellite service, often associated with the broadcasting industry.
TT&C	Telemetry, tracking and command. Used in both satellite and space science communications where links are used to monitor data from a satellite on its health and functioning (telemetry); track the location of the satellite (tracking); and send commands from the ground to the satellite to satisfy operational mission requirements or to respond to emergency conditions (command).
Uplink	Earth to space communication going up from a ground (or aircraft or ship) based station to a satellite.
User terminal	Typically comprising a small antenna and associated equipment to connect to a satellite.
WRC	World Radiocommunication Conference. The WRC reviews and revises the Radio Regulations. They are held every three to four years. The next WRC will be held in Geneva in 2023 and is referred to as WRC-23.
WT Act 2006	Wireless Telegraphy Act 2006. We authorise the use of the radio spectrum by granting wireless telegraphy licences under the WT Act.