Ofcom
making communications work
for everyone

Space Spectrum Strategy

CONSULTATION:

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Annex

1. Overview

This document sets out Ofcom's proposed strategy for managing radio spectrum used by the space sector.

The space sector and its use of spectrum are growing. Operators such as OneWeb and SpaceX are deploying large numbers of new non-geostationary orbit (NGSO) satellites which can provide broadband to homes and businesses in remote locations. Data on climate change collected by Earth observation satellites is increasingly important, and there has been a general increase in space activity. For instance, the number of space launches increased by almost 60% between 2017 and 2021. These changes mean we need to review where to focus our efforts in the space sector.

Our strategy and priorities – in summary

We want spectrum to enable the space sector to deliver even greater benefits in the future, and for the sector to use spectrum efficiently.

Our strategy particularly focuses on the opportunities and challenges raised by NGSO satellite communication systems. We want to see efficient spectrum use by these systems and for as many as possible to offer services to people and businesses in the UK.

We have set out a range of actions in three areas where we think our efforts will have the greatest benefit over the next two to four years:

- **Communications –** The size of the satellite communications sector is increasing, both in terms of the number of satellites and the number of new entrants, and NGSO satellite systems are creating new spectrum management challenges. We have introduced a new NGSO licensing process and will pursue improvements to international NGSO rules. We will also consider providing access to spectrum that could boost the capacity of a range of satellite services.
- **Earth observation and navigation –** Data from Earth observation satellites provides benefits to many different sectors, such as agriculture, emergency services, climate monitoring and weather forecasting. We will consider protection for UK sites used for downlinking data from Earth observation satellites, and ensure that Earth observation sensors in space get appropriate protection from other users.
- **Understanding and enabling access to space –** Given the rapidly rising numbers of space objects and proposals for mega-constellations, there are growing concerns across the space community about the potential for space debris and safe access to space. One change that we will consider is appropriate access to spectrum for radars to track objects in space.

We are also planning cross-cutting work to further embed our overall spectrum management strategy. For example, we want to make it even easier for a broad range of space users to access spectrum. Some innovative projects in the space sector – particularly those using small satellites or 'cubesats' – do not always fall neatly within one of our existing licence products. So, we will identify frequency and authorisation options that may be relevant for these new cubesat applications.

Background

1.1 The space sector is one of the biggest users of spectrum delivers a wide range of benefits to people, businesses and public sector users in the UK. These include satellite broadband, broadcast TV services, global positioning services and communications in emergency situations. Satellites used for Earth observation services are also important in collecting data used to monitor weather and climate change.

1.2 The use of spectrum by space services involves both domestic and international regulation:

- Ofcom is responsible for managing spectrum in the UK, making sure it is used in the best interests of everyone in the UK. In the space sector this includes authorising satellite equipment on the ground, as well as on UK planes and ships.
- International regulations govern the use of spectrum by satellites in space. Ofcom is responsible for representing the UK internationally on matters relating to spectrum. In the space sector this includes managing international satellite filings for UK companies and influencing the development of new international rules for spectrum use by satellites.

1.3 Our previous strategy for spectrum work in the space sector was set out in January 2017.[1] The focus of that strategy was to enable growth in satellite broadband and Earth observation, and it set out a workplan which we have now largely delivered. The core principles of that strategy remain relevant. However, since 2017 the sector has undergone significant change and rapid expansion.

1.4 These developments create new challenges for regulating the space sector's use of spectrum. More space users deploying more satellites, particularly large numbers of NGSO satellites, will put growing pressure on the use of spectrum. The increased number of satellites makes coordination to avoid interference between systems increasingly complex. The complexities of managing interference between NGSO systems could also have implications for competition. In light of these challenges, we need to review where best to focus our efforts in the space sector.

Next steps

1.5 This consultation closes on 24 May 2022. We welcome stakeholder input on our proposed strategy, including evidence on future trends, additional issues that it would be beneficial for us consider and whether specific issues should be of high priority and why. We aim to publish our finalised strategy in Q2 2022/23 taking account of responses.

1.6 In addition to the actions identified in our proposed strategy, we have a range of on-going actions that we will continue to deliver, including our role as UK filings administrator and representing the UK internationally in the lead up to the World Radiocommunication Conference 2023 (WRC-23) and beyond.

[1] Space Spectrum Strategy 2017

2. Introduction

This document consults on our proposed space spectrum strategy

2.1 This document seeks stakeholder input on our proposed strategy for how we manage the spectrum used by the space sector, particularly spectrum used by non-geostationary orbit (NGSO) satellite communication systems.

2.2 Use of the radio spectrum ("spectrum") is essential for all wireless communications, and the space sector depends on spectrum access to deliver a wide range of benefits to people, businesses and public sector users in the UK, including:

- connectivity for remote locations, including consumer broadband, backhaul for mobile base stations;
- connectivity for planes and boats;
- monitoring of Earth from space in order to inform weather forecasting, understanding of climate and providing satellite imagery (Earth Observation);
- global positioning, navigation and timing;
- space weather monitoring;
- study of the solar system and universe;
- satellite TV direct to consumers;
- video distribution and contribution (e.g. satellite news gathering);
- emergency communications for aircraft and maritime users; and
- satellite communication during disasters when terrestrial networks are unavailable.

2.3 Other space applications that support the growth of the space sector include space launch, in-orbit servicing and tracking of space debris.

2.4 The purpose of our strategy is to:

- identify the key trends in the sector affecting spectrum use;
- given these trends, to identify the broad areas we propose to focus on and specific activities in those areas over the next 2 – 4 years;
- identify cross-cutting activities to take account of our new spectrum management strategy;
- set out our ongoing activities that support delivery of the strategy; and
- identify further activities to address the unique challenges and opportunities raised by the growth of NGSO satellite communication systems.

2.5 This strategy builds on our 2017 strategy and takes account of developments in the space sector in the last five years as well as issues that may develop over the next 5 – 7 years. This reflects the timeline for notification of satellite filings and the upcoming cycle of World Radiocommunication Conferences (WRCs) in 2023 and 2027. Most of the actions we propose in this strategy would be implemented over, approximately, the next 2 – 4 years. Information on longer term trends gathered through this consultation will contribute to our thinking on the agenda for WRC-27, which will be discussed and agreed at WRC-23.

2.6 These proposals also reflect our broader spectrum management strategy, published in July 2021.[2] Our proposals for NGSO satellite systems build on the changes we made to the licensing of these systems in December 2021.[3]

Why we need to refresh our space sector strategy

2.7 We develop sector spectrum strategies to consider significant changes in major spectrum-using sectors, to review trends and to set out roadmaps for our work. This is important as there is increasing and competing demand for spectrum from many sectors, which continually changes over time as technology advances and business needs change. To ensure our strategies reflect these changes, we engage with stakeholders to maintain and improve our understanding of their spectrum use and future requirements.

2.8 The space sector is one such sector where it is important for us to take a strategic approach. The sector is fast-moving and includes emerging technologies that deliver improved services to UK consumers, for example non-geostationary orbit satellites (NGSOs) and the improved connectivity they could offer some UK citizens and consumers. The sector is global: a satellite system usually provides services to a wide geographic area, rarely just the UK, so the regulatory rules for satellites accessing spectrum at specific orbital locations are set internationally. Space sector strategies provide an opportunity to engage with its diverse stakeholders to identify trends and set priorities.

2.9 We refresh our sector strategies when there is evidence of significant changes in that sector and to consult with stakeholders on our up-to-date policy priorities. As such, it is a good time to refresh our existing space spectrum strategy due to the pace of change in the sector in the last five years, as we discuss in section 3. Some of the developments include the large numbers of NGSO satellites that are being deployed; the increasing importance of information collected by Earth observation satellites on climate change and the increase in space activity in general.

How does the space sector use spectrum?

2.10 The UK has a growing space sector of some 1200 organisations comprising manufacturers, support services, satellite applications companies, research and test facilities, finance bodies and space ports.[4]

2.11 The sector relies on access to spectrum for a very wide range of purposes, including to provide global communication services, to monitor short-term and long-term changes to our environment on Earth and to deepen our understanding of the solar system and wider universe. Spectrum is used for telemetry, tracking and command (TT&C) for satellites and launch vehicles. Space organisations like NASA and the European Space Agency (ESA) use

[2] Statement: Supporting the UK's wireless future (ofcom.org.uk)
[3] Statement: Non-geostationary satellite systems – licensing updates (ofcom.org.uk)
[4] UK Space Sector Landscape Map - KTN (ktn-uk.org)

spectrum to communicate with the International Space Station, missions to the moon and in future missions further afield in our solar system.

2.12 Space services rely on a combination of internationally agreed spectrum allocations and nationally authorised spectrum. Satellites rely on internationally recognised satellite filings and national authorisations for earth station deployments within each nation.

What is Ofcom's role regarding the space sector?

2.13 Ofcom's overall mission is to make communications work for everyone. Each year we set out our priorities in a plan of work. Areas where our work in the space sector contributes to the wider priorities from our 2022/23 plan of work[5] are set out below include the following:

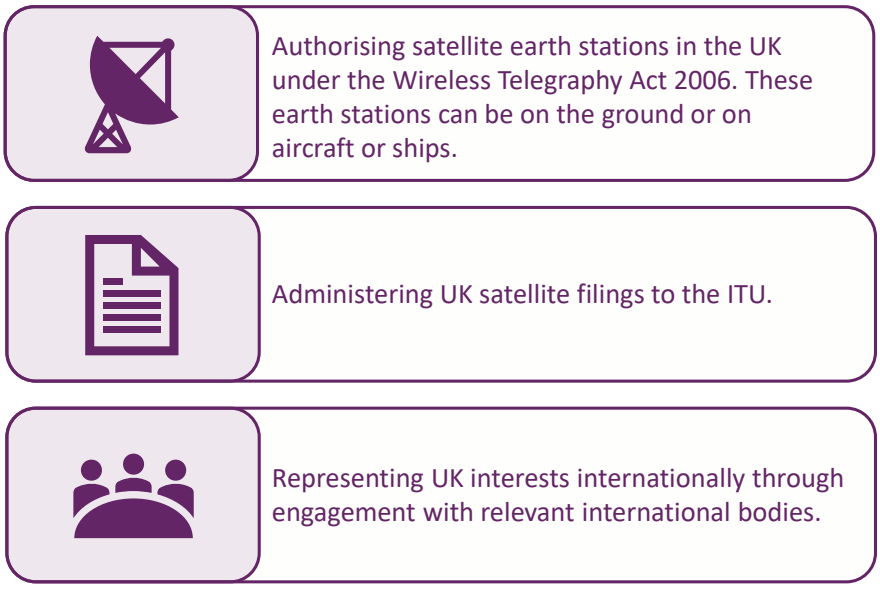
- investment in strong, secure networks – our work supports the use of satellites in communications networks, both for backhaul and for resilience purposes;
- getting everyone connected - we are seeking to enable NGSO satellite systems to grow and compete, which could offer some UK citizens and consumers improved connectivity;
- supporting and developing UK media – by enabling the use of spectrum for satellite broadcasting, we help ensure the availability of a wide range of TV content; and
- enabling wireless services in the broader economy – by promoting innovation and spectrum sharing we encourage the effective use of spectrum.

2.14 Ofcom's principal legal duty is to further the interests of citizens and consumers in relation to communications matters. We also have a specific legal duty to ensure UK radio spectrum is used in the most efficient way. We do this by analysing the use of spectrum to support our strategic reviews, inform our policy, and plan for future spectrum requirements. [6] We rely on market mechanisms where possible and effective, but may also take regulatory action where necessary.

2.15 Ofcom has three spectrum functions regarding the space sector:

[5] Consultation: Ofcom's proposed plan of work 2022/23

[6] We have set out our spectrum role recently in our spectrum management strategy: Statement: Supporting the UK's wireless future (ofcom.org.uk)



Spectrum Management & Earth Station Licensing

2.17 We authorise use of the radio spectrum in the UK by granting wireless telegraphy licences under the Wireless Telegraphy Act 2006 (WT Act).[7] We also make regulations exempting users of particular equipment from the requirement to hold such a licence.[8]

2.18 Ofcom licences cover the use of equipment to transmit signals. We also grant Recognised Spectrum Access ('RSA') to receive-only earth stations (ROES) to protect their use in specific spectrum bands. We also investigate reports of radio interference and may prosecute, or take other enforcement action, to protect against interference or other harm.

Satellite filings

2.19 Satellites can transmit across national borders over multiple individual states, meaning their use of spectrum needs to be managed globally. This management process, involving the processing of 'satellite filings,' is administered and overseen by the International Telecommunication Union (ITU), a specialised agency of the United Nations.[9] 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. The ITU handles satellite filings on a first-come, first-served basis. Filings are considered

[7] Examples of the licences we grant space operators include Permanent Earth Stations, NGSO Earth Stations, Transportable Earth Stations, Earth Station Network Licences and GNSS repeaters. See: Apply for a satellite earth station licence - Ofcom.
[8] A list of frequencies that can operate without a licence can be found in our Interface Requirement2016: ir2016.pdf (ofcom.org.uk).
[9] The rules governing the use of the electromagnetic spectrum by satellites are included in the 'Radio Regulations', an international treaty to which the UK is a signatory.

'brought into use' once a satellite is launched and placed within the relevant orbital location or plane.

2.20 As the spectrum available to satellites is a scarce resource many satellite networks/systems consist of overlapping frequency assignments. Therefore, satellite filings are coordinated both nationally and internationally, ensuring that the signals they transmit and receive do not cause, or suffer from, harmful interference. This system operates basically on a first-come, first-served basis, whereby later registrations must coordinate with prior filings. However, regardless of the date of their filing, all operators need to make every effort to accommodate these coordination discussions, working in good faith to reach coordination agreements.

2.21 As the notifying administration of the UK, Ofcom submits and manages all satellite filings to the ITU on behalf of organisations registered in the UK.

International engagement and representation

2.22 International spectrum rules are negotiated at the ITU and published in the Radio Regulations.[10] Changes to the rules are made every four years at the World Radiocommunication Conference (WRC) held by the ITU. Ofcom exercises "international negotiation functions" representing UK interests[11] at the ITU[12], including by leading the UK delegation at WRC meetings. The next WRC is scheduled to take place in 2023. Ofcom also represents UK interests at the European Conference of Postal and Telecommunications Administrations (CEPT).

2.23 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 take account of wider UK public interests in our international representation work as we consider appropriate.

Our ongoing activities

2.24 We have several ongoing activities, set out below, that we undertake to implement our functions. These will continue alongside the additional actions identified as part of our proposed strategy in the rest of this document.

Horizon scanning allows us to respond to space sector developments

2.25 We monitor developments in the space sector to help us track emerging trends and understand the potential impact of new technologies. We set out such trends in our Technology Futures publication[13] and the next section.

[10] Radio Regulations (itu.int)
[11] See Annex A to Memorandum of Understanding at: mou_2004_international_rep.pdf (ofcom.org.uk).
[12] We also represent the Channel Islands, the Isle of Man and the British Overseas Territories at the ITU, see: mou_ots_2007.pdf (ofcom.org.uk).
[13] Report: Technology Futures – spotlight on the technologies shaping communications for the future (ofcom.org.uk)

2.26 Since 2017, we have been collecting data on satellite-delivered home broadband users in the UK. As new satellite broadband networks become available to UK consumers, we will work with service providers to monitor take-up and the quality and quantity of their service. This will be reported in our Connected Nations report.

We engage with our stakeholders to understand their needs

2.27 The UK space sector is a diverse community that includes government departments, mature satellite operators, SMEs, academia and (more recently) space launch operators. We will continue to engage with all parts of the sector to understand their trends and needs, and, where appropriate, help them understand our role and how we can help them engage with (spectrum) regulatory issues. This includes:

a) We work with **government departments** to identify and enable new space services. We discuss how we will collaborate below.

b) We will continue to engage to understand the trends in the space services of **commercial satellite operators** and consider relevant updates to our authorisations, where appropriate. We will engage with the sector on international matters through the International Frequency Planning Groups.

c) We work closely with **international organisations** in the space science area to understand their issues and their use of the spectrum, including the ESA, the European organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Square Kilometre Array (SKA) organisation.

d) We encourage early engagement on new projects and innovative services from all parties – whether **academics, government officials or start-ups.**

2.28 We make information available to stakeholders, including The UK's Frequency Allocation Table (FAT) and information regarding the current use of spectrum and licence-holders can be viewed on the Ofcom Spectrum Information Portal. We have developed specific landing pages for space launch authorisations and NGSO constellations in the UK. We intend to publish FAQs for earth station licences on our website.

2.29 Much of the innovation in this sector is anticipated to come from smaller and/or newer organisations which may be less familiar with the satellite regulatory environment than more established operators. We will therefore review the information we make available to ensure this is easy to access and understand. We will also continue to offer training for new entrants. This will be advertised on our website.

We collaborate with other regulators and government

2.30 We collaborate with other regulators and government when our work and their work intersect. In particular, as already mentioned, we collaborate closely with the Civil Aviation Authority (CAA), the other regulator along with ourselves with a remit that covers space. Specific areas where we collaborate with the CAA include:

- satellite filings/satellite licences;

- Radio Frequency (RF) communications required for safe operation of satellites, e.g. frequencies for TT&C;
- movements of UK satellites for spectrum purposes, e.g. Bringing into Use satellite filings;
- spectrum authorisations for space launch operations from the UK; and
- international negotiations at the ITU pertaining to space launch and safe operations of satellites.

2.31 We also collaborate, as appropriate, with relevant government departments and agencies including the Department for Business Energy Innovation and Science (BEIS), the UK Space Agency (UKSA), the Meteorological Office (Met Office), the Ministry of Defence (MoD), the Foreign Commonwealth and Development Office (FCDO) and the Department for Culture, Media and Sport (DCMS).

2.32 The UK's National Space Strategy [14] outlines the Government's goal to grow the UK space economy and sets out an intention to work with Ofcom (among other organisations) to meet the needs of space users. Our space spectrum strategy complements the Government's aims by supporting innovation and creating a transparent and predictable regulatory framework. This in turn supports investment in the UK space sector.

2.33 We welcome views from stakeholders on other ways that we might bring together stakeholders, regulators and government to enable richer collaboration on space sector issues.

We process satellite earth station licence requests

2.34 We process applications for satellite earth station licences and grants of RSA for ROES. A licence is not required for receive-only radio equipment but a grant of RSA gives formal recognition to this equipment, enabling Ofcom to take account of it on a comparable basis to licensed use.

2.35 Many licence requests are routine requests ones that we can process easily using standard procedures, although we may also consider bespoke requirements as appropriate.

2.36 We will monitor our new process for handling licence requests for non-geostationary orbit satellite systems, with a view to making it run as efficiently as possible.

We manage satellite filings and will continue to develop our procedures

2.37 As noted above, we submit and manage all satellite filings to the ITU on behalf of organisations registered in the UK.

2.38 As of 1 January 2022, we manage 309 satellite filings on behalf of 38 operators. The number of operators filing through the UK has continued to increase over recent years, up from 25 operators in 2016. Around 20% of UK satellite filings are for NGSO satellite

[14] HM Government – National Space Strategy September 2021 (publishing.service.gov.uk)

systems and a growing proportion of these filings come from smallsat or cubesat operators.[15]

2.39 We manage filings in a thorough, transparent and predictable way, consistent with international rules, by following a set of published procedures.[16] We have also introduced an online portal which not only streamlines the process for satellite operators to submit BR-IFIC comments, but also the way they are handled within Ofcom.

2.40 We intend to initiate a review of our procedures for the management of satellite filings and make changes, ensuring requirements remain transparent and, where appropriate, to reflect the latest international rules.

We represent UK interests internationally

2.41 Ofcom represents the UK at international bodies relating to spectrum. We have an on-going process to engage with stakeholders in preparation for relevant international meetings. The International Frequency Planning Group (IFPG) and its Working Groups are the main route for stakeholders to provide input into Ofcom's international spectrum work.[17] We engage with UK satellite interests through IFPG Working Group 3 and science interests through IFPG Working Group 2.

We monitor and take enforcement action where needed

2.42 In general, in order to manage the risk of harmful interference, we may monitor spectrum use, check compliance with authorisation terms, investigate and, when appropriate, take enforcement action if harmful interference occurs. We do not guarantee interference-free spectrum, as interference can arise from a range of sources (including faulty or deficient equipment or natural atmospheric conditions).

2.43 In relation to space sector spectrum use, two areas of our work to highlight are:

- **Global Navigation Satellite Systems (GNSS).** We actively monitor online sales platforms, removing GNSS jammers from the market and taking appropriate enforcement action. We also work with law enforcement agencies to understand the impact of jammers on the commission of offences and prevention and detection of crime. Stakeholders who experience persistent interference to the reception of GNSS signals may report incidents to our Spectrum Monitoring Centre. We will provide advice and assistance and may investigate further.[18]
- **NGSO satellite systems.** We have recently introduced new licence conditions into NGSO licences which provide greater ability for us to deal with interference to/from NGSO systems. We are also developing our satellite monitoring capabilities and

[15] Smallsats and cubesats are both types of satellites of small size and low weight.
[16] Satellite filings - Ofcom
[17] International Frequency Planning Group (IFPG)
[18] Persistent interference here may include: constant interference at one or more locations, interference when travelling through a location over a period of time, interference at particular times of the day, interference when particular vehicles are in the vicinity.

measurement activity, in particular (as discussed in section 6) we are developing our national capabilities for investigating interference to or from NGSO systems and our understanding of the resilience of NGSO systems to interference.

2.44 In the event operation of a UK-filed satellite network causes harmful interference to other satellite networks, we can instruct satellite operators to cease transmission in line with our satellite filing procedures.

The remainder of this document outlines our strategy and seeks comments

2.45 We structure the rest of this document as follows:

- In the next section (**section 3**) we set out key trends relevant to our strategy.
- We then (**section 4**) set out our strategic objectives and priority work areas.
- Next (**section 5**), we describe the specific actions in each of our work areas.
- Then (**section 6**), we describe our strategy and actions specifically relating to NGSO communication systems. This forms a crucial part of our overall strategy and builds on the work we have already done to update our NGSO licensing regime.
- Finally (**section 7**), we set out the next steps for this consultation and how to respond to it.

3. The context for a strategic refresh

The space sector is changing

3.1 Our 2017 strategy continues to provide a strong foundation for our approach to the space sector. It has informed recent work that has benefitted people and businesses in the UK. However, the space sector has changed since 2017. New trends are emerging. Some of these changes relate to the whole space sector, while others relate to specific areas within it. We covered many of the technology developments in the space sector in our 2021 Technology Futures report.[19] The analysis below builds on that report.

Some developments are sector-wide

Deployment is speeding up and costs are falling

3.2 The average size of a satellite is decreasing, falling from close to 3000 kg to less than 500 kg between 2010 and 2020.[20] Meanwhile, the time to build a satellite has fallen: SpaceX has said that it is building 120 satellites a month, twenty times faster than a previous peak by another operator, Iridium.[21] Oneweb says it is able to build up to two satellites a day at its Florida factory.[22] Thales Alenia Space plans to build a satellite a day for Telesat's new Lightspeed constellation.[23]

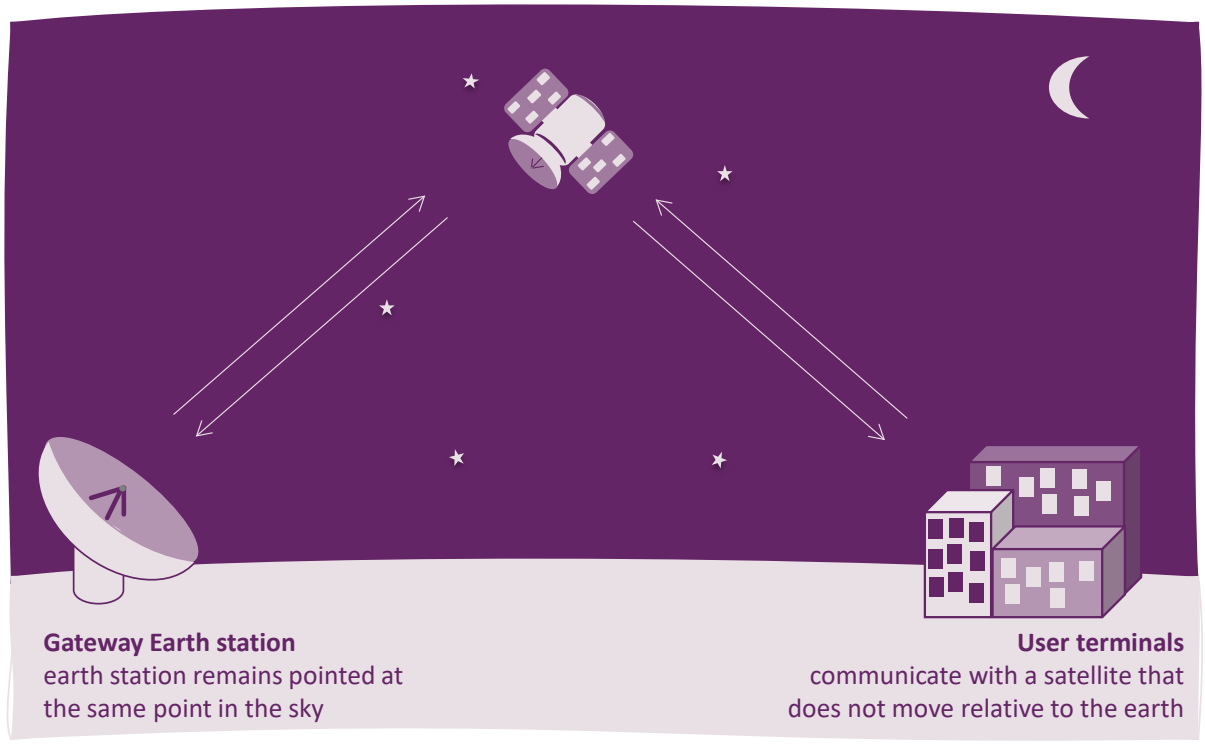
3.3 At the same time, the costs of actually getting a rocket into space have come down. SpaceX has helped to reduce the cost of launch from well over $100 million per rocket to around $47 million through the development of reusable rocket stages. Costs to satellite operators are now as low as $1,400 per kg, having fallen from more than $10,000 per kg before 2000.

Satellite technology continues to evolve

3.4 **Geostationary orbit (GSO) satellites** have traditionally been the primary way of delivering satellite communication services. Here, the sector continues to innovate. Technologies adopted from the mobile sector such as small cell spectrum frequency reuse and higher frequency feeder links continue to increase the overall capacity of these satellites. Software-defined satellites give operators more flexibility over the frequencies and service areas, allowing them to adapt to new markets. Beam hopping and precoding technologies are being adopted to increase spectral efficiency while cloud services and artificial intelligence (AI) are improving network management.

[19] Report: Technology Futures – spotlight on the technologies shaping communications for the future (ofcom.org.uk)
[20] BryceTech - Reports
[21] SpaceX: Starlink satellte production now 120 per month (cnbc.com)
[22] Factory | OneWeb
[23] Thales Alenia selected to build Telesat's broadband constellation - SpaceNews

Figure 1: GSO satellites remain at a fixed point in the sky



3.5 Falling costs and faster production have enabled the mass deployment of **NGSO satellites**. New services based on constellations of NGSO satellites in low Earth orbit (below 2000km) and medium Earth orbit (2000 – 35,786 km) are under development for communication, sensing and positioning services. These networks have the potential to offer:

i) lower latency communication services;

ii) faster revisit times and/or persistent sensing of Earth and space, reducing time between measurements;

iii) more accurate and/or resilient positioning, navigation and timing.

3.6 We refer to these collectively as NGSO constellations or NGSO satellite systems. Extremely large constellations numbering hundreds or thousands of satellites we also refer to as mega-constellations. These new constellations will mean a significant increase in the total numbers of satellites in orbit.[24] They will create new high-capacity connections for people and businesses across a range of services.

3.7 Due to their dynamic nature, NGSO mega-constellations also present new challenges for spectrum management in the UK.[25] We articulated some of these challenges in our NGSO licensing consultation, published last year. Others we address in section 6.

[24] SpaceX alone has been reported to be planning 12,000 satellites by 2026, 2 – 3 times the total number of operational satellites in orbit today, with potential for another 30,000 satellites. See: Starlink: SpaceX's satellite internet project | Space.

[25] As we explained in our recent NGSO Licensing Consultation: Consultation: Non-geostationary satellite systems – Licensing updates (ofcom.org.uk).

3.8 Designs for NGSO systems are also continuing to evolve as operators look to adopt newer satellite and antenna technologies, inter-satellite links, different frequencies and different orbital planes. As we will discuss in section 6, these could have implications for spectrum management both nationally and internationally, therefore they are a priority for our strategy and discussed in a dedicated section in this document.

Figure 2: NGSO satellites move across the sky

3.9 NGSOs in low Earth orbits can detect (and close the link with) much fainter signals on the ground. This means NGSOs can be used to map radio transmissions, track moving objects and could extend the coverage of terrestrial networks in a range of frequencies. NGSO services will also soon complement GSO communications services (discussed further below), helping to deliver broadband services to remote locations, passengers and crew on a greater number of ships and aircraft, as well as having implications for industrial Internet of Things (IoT) in sectors such as agriculture, mining and shipping.

3.10 Growing NGSO constellations will also create a need for more and better tracking of satellites in space, including deployment of more and higher performance radars.

Other developments relate to key use cases in the space sector

3.11 There are further developments that, while they do not refer to the whole space sector, do relate to key use cases within it. We set out these developments below, beginning with those areas where in our view there have been the most significant changes with the greatest potential to have regulatory impacts.

Satellites remain important for communications and could contribute to improved communications services in the UK and globally

3.12 Satellites play a diverse role in communications. They are used for internet access, providing broadband to homes and communities in remote locations. They are increasingly used to provide connectivity for maritime and air passengers, both as a stand-alone service or integrated with "air-to-ground" terrestrial services. Looking forward, there are proposals to use satellites to extend wireless networks for a variety of applications.

3.13 The UK already has relatively good coverage of fixed broadband services, with almost all premises receiving a decent broadband service of 10 Mbps. Our Connected Nations report estimates that 0.4% / 123,000 homes and businesses currently do not have access to a decent fixed or fixed wireless access broadband connection.[26] 96% of residential premises have access to a superfast broadband connection. We estimate that satellite broadband users are in the low tens of thousands (from both GSOs and NGSOs). The market for future communications services delivered via NGSOs may well come in other countries than the UK where broadband coverage is not of the same level or in situations where terrestrial networks are disrupted by conflict or natural disasters. However, even in the event uptake of direct-to-consumer satellite services in the UK remains relatively low, satellite could provide a means to improve the resilience of terrestrial networks in the event of natural disasters such as storms or floods.

3.14 There are several areas that may come to depend more on satellites services, although it is too early to judge whether these will be significant markets in the UK given the growing reach of terrestrial communication networks:

- Satellite-delivered IoT services could help provide connectivity for locations where environmental monitoring or agritech are out of range of terrestrial networks.
- Satellites may play a role in providing back-up and resilience for utilities networks.
- Satellites could improve mobile services in areas with poor coverage.[27] As a result of forthcoming 3GPP standards (Release 17), satellites can be integrated more easily into mobile networks to provide backhaul for mobile communications in more remote locations.[28] Looking forwards, studies are on-going to explore whether satellites in low Earth orbit might also be used to connect to unmodified mobile handsets, effectively moving base stations into space. This could extend the range of mobile networks into areas where it is not currently cost-effective to deploy base stations or provide a back-up communications network for emergencies and natural disasters.

3.15 We will monitor how these areas develop over the course of our strategy.

[26] Connected Nations 2021: UK report (ofcom.org.uk)
[27] SES and Inmarsat have set up the Non-Terrestrial Connectivity Solutions (NTCS) Project Group to encourage the emergence of a technology ecosystem that allows satellites to support 5G, Non-Terrestrial Connectivity Solutions - Telecom Infra Project.
[28] Release 18 will examine mechanisms to enable greater integration between satellite and terrestrial networks, including techniques to share the same spectrum.

There are increased needs related to climate and weather

3.16 The need for accurate climate monitoring and weather forecasting is increasing. Scientists using satellites to measure particular natural phenomena require access to unique frequencies for their measurements.[29] These frequencies need both national and international protection.

3.17 In particular, since our last space strategy in 2017, responding to the threat posed by global warming has become a priority both in the UK and internationally.[30] The UK parliament passed legislation requiring the Government to reduce net emissions of greenhouse gasses to 100% of 1990 levels ("net zero") in 2019 and published its strategy for reaching this target last year.[31]

3.18 Commercial Earth observation services are also growing, alongside existing science and government missions. Government Earth observation programmes have traditionally focused on greater imagery resolution and more accurate measurements, resulting in large satellites carrying cutting-edge, high fidelity sensors. However, newer commercial operators such as Planet and Spire have shown that constellations of small satellites carrying commercial-off-the-shelf electronics and cameras can provide more persistent sensing and real time data. This could, for example, improve storm-tracking and provide more accurate weather prediction. We also anticipate commercial operators to use a wider range of sensors. Consequently, government agencies and scientists are also looking to complement their single satellite missions with constellations in the future.

3.19 Such growth in the numbers of players and Earth observation satellites could increase the numbers of filings and increase the volume of data requiring downlink in the UK.

3.20 Earth observation satellites will also collect more data about the Earth and climate, which operators will need to downlink to the ground and distribute to users. Operators are looking to employ a range of solutions to cope with the demand for high bandwidth, time-sensitive data.[32] Some are also looking to employ optical inter-satellite links and on-board processing, which may mitigate some of this demand.

There is growth in general space activity, including around launches and space weather

3.21 The broader industry trends set out above mean that general space activity is increasing.[33] The rapid increase in satellite numbers is driving demand for more commercial launch services. Small satellite operators who opt to "ride-share" often have to wait to secure a launch and have less control over which orbit they end up in. As a consequence, there is a

[29] Phenomena measured include water, oxygen and carbon dioxide.
[30] Statement-Space-Spectrum.pdf (ofcom.org.uk)
[31] Net Zero Strategy: Build Back Greener - GOV.UK (www.gov.uk)
[32] Including higher capacity links, inter-satellite links or larger networks of ground stations around the world, as well as new stations to downlink data at higher frequencies in the UK.
[33] For instance there were 134 space launches in 2021, compared to 84 in 2017, an increase of almost 60%. Data from Launch Schedule - RocketLaunch.Live.

growing interest in developing new launch platforms, which give commercial satellite operators more choice. The UK is planning to commence launch services this year.

3.22 New markets are also under development. One example are in-orbit services to remove broken satellites from orbit and address the problem of space debris and several companies are now exploring the concept of reusable satellites[34].

3.23 There is also a renewed interest in manned space exploration. NASA plans to land people on the moon again in the 2020s as part of its Artemis programme. The UK will be supporting the NASA mission under the Artemis Accords.[35]

3.24 Satellites are particularly vulnerable to the effects of space weather – high energy particles streaming from the sun. Recently there has been UK investment in space weather monitoring capabilities, including the European Space Agency's L5 project to monitor solar activity and provide data for solar forecasts.[36]

Satellite broadcasting is relatively stable but there is potential for market changes

3.25 In the UK, 27.1% of homes in the UK have satellite pay TV, while 4.8% of homes have a free to view satellite service.[37] Changing viewing habits in Europe and the US mean an increasing amount of content is being viewed online via streaming video on demand services, such as Amazon and Netflix. In the UK, 75% of households surveyed for Ofcom's Technology Tracker said they use a subscription video on demand (SVOD) service.[38] However, in other parts of the world satellite TV remains important.

Emergency and disaster relief services remain vital

3.26 Emergency distress beacons connecting to satellites are used by aircraft, ships, yachts, as well as hikers/climbers operating in remote and extreme environments. Satellites can also be used to provide temporary communications, e.g. via satellite phones, in the aftermath of natural disasters or during conflicts when terrestrial networks are unavailable. Both types of service remain vital.

3.27 In addition, constellations of small satellites in low Earth orbit make our seas and airspace safer by detecting signals broadcast by ships and aircraft to avoid collisions.[39] The use of satellites using these signals to provide global tracking systems has removed black spots that were beyond the reach of shore-line radar systems. It is hoped, as a consequence, that aircraft will no longer be able to disappear from air traffic controllers like Malaysian Airlines flight MH-370, which crashed into the Pacific Ocean.

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[34] Space Forge - Making Space Work For Humanity
[35] Artemis_Accords_signed_13Oct2020__002_.pdf (publishing.service.gov.uk)
[36] ESA - The "no name" space weather mission
[37] BARB Establishment survey.
[38] Technology Tracker 2021
[39] Automatic Identification System (AIS) AIS transponders (imo.org); Automatic Dependent Surveillance– B (ADS-B) untitled (icao.int).

The broader spectrum context and our new spectrum management strategy also drive our refresh

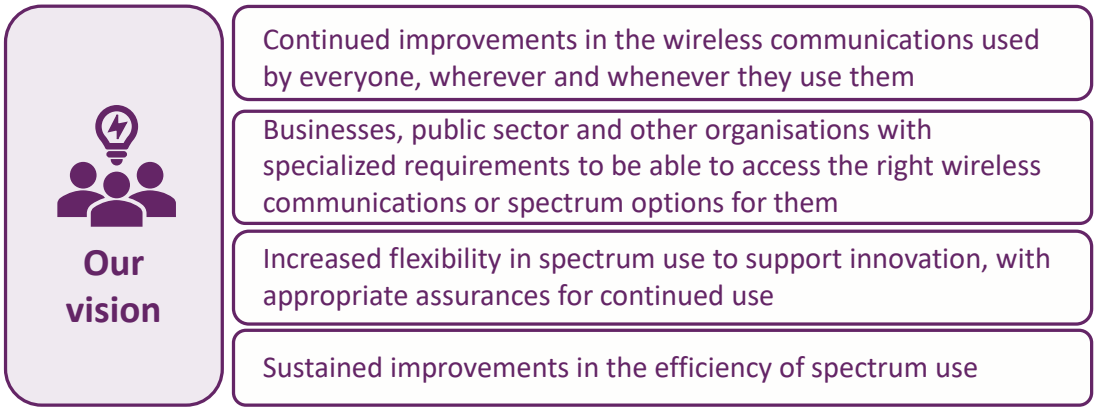
Demand for spectrum is increasing

3.28 Beyond the space sector, the broader spectrum context is changing, making a strategic refresh appropriate. These developments could impact how space sector applications can use spectrum. There is an increasing diffusion of and reliance on wireless technologies throughout society, in sectors such as utilities, healthcare and agriculture (agritech). This can enable benefits in economic and social terms, but also means increased demand for spectrum. Meanwhile, advances in technology mean that much higher frequencies can be used than ever before and new demand is emerging for bands that were not considered "prime" spectrum bands several years ago.[40]

We have a new spectrum management strategy

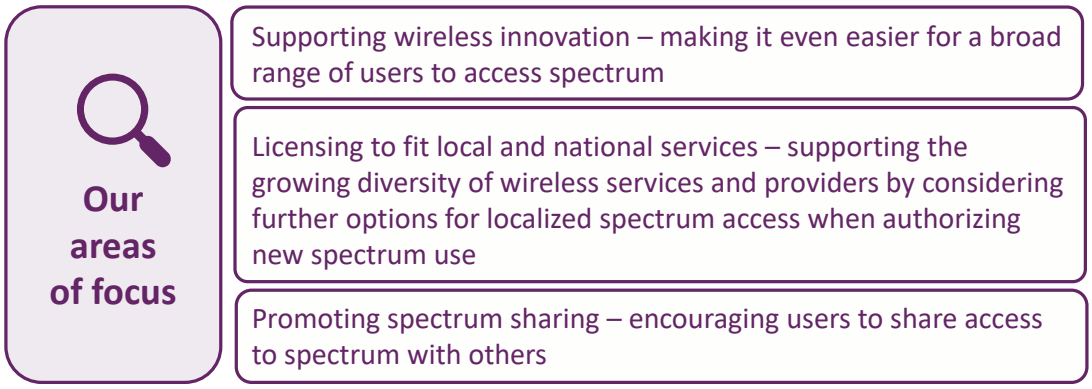
3.29 We revised our approach to spectrum management in July 2021.[41] We must set the needs of individual sectors like the space sector in the context of increasing overall demand for a wide range of wireless services. Access to UK spectrum for one user must be balanced against the demands of other users and the benefit they will bring to UK consumers. It must also be proportionate – employing only the spectrum needed and using it in a way that is mindful of other users. We should ensure that we reflect the changes to our overall spectrum management strategy in our space spectrum strategy.

3.30 In the strategy, we set out a new spectrum management vision to enable growth and innovation:



3.31 To realise our vision, we identified three areas of increased focus for the next decade:

[40] We looked at these and other trends in our spectrum management strategy consultation: Statement: Supporting the UK's wireless future (ofcom.org.uk).
[41] Statement: Supporting the UK's wireless future (ofcom.org.uk)



3.32 We will reflect our spectrum vision and areas of increased focus across the breadth of our refreshed space spectrum strategy. We have also identified some specific actions which are particularly driven by our focus on promoting spectrum sharing.

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?

4. Our strategic objectives and priorities

4.1 The two key questions driving our strategy, which are addressed in the remainder of this document, are:

- **Where should we focus our spectrum management efforts (section 4 and 5)?** The space sector is diverse, with growth in many areas. There are competing demands among different users within the sector and between space and services outside the space sector. We need to identify the broad areas to prioritise and the specific issues within those areas where our actions can bring the greatest benefit.
- **How should we respond to the challenges introduced by new NGSO satellite systems (section 6)?** New NGSO communication systems with hundreds or thousands of satellites promise improved services, but also create significant new spectrum management issues. We need to develop a strategy that allows us to meet these challenges to ensure UK citizens and consumers receive the benefits of these new systems.

4.2 The rest of this section sets out our objectives and the work areas we propose to prioritise.

Objectives for our work in the space sector

4.3 Given our overall spectrum management strategy and space sector trends we have identified two overall objectives for our space spectrum strategy:

a) We aim for spectrum to enable growth in the benefits that the space sector delivers for people and businesses in the UK.

b) We aim for spectrum to be used efficiently by the space sector and not create undue constraints on the growth of other users. We will place particular emphasis on promoting spectrum sharing, in accordance with our broader spectrum management strategy,[42] through:

i) Use of better data and more sophisticated analysis when assessing the conditions for sharing between space spectrum users and with terrestrial spectrum users. This includes using information regarding the real performance of satellite equipment and services where this is available (rather than limits in standards or specifications).

ii) Space system (including, for example, user equipment and sensors) being more resilient to interference from their neighbours. When space users are deploying, redesigning or upgrading systems they will need to ensure that they are using equipment that offers good resilience to interference and does not itself cause interference to other users. We do not generally expect to act on interference if it

[42] Statement: Supporting the UK's wireless future (ofcom.org.uk)

is a result of the poor performance of receivers or wider systems, i.e. if they are impacted by signals outside the band in which they are receiving.

iii) An efficient balance between the level of interference protection given to one service and flexibility for others to transmit. This includes expecting stakeholders to present evidence-based analysis to support the level of protection they may be seeking.

4.4 In addition, as discussed above, one of the key questions for our strategy is how we should respond to the challenges introduced by new NGSO satellite communication systems. Our future work will have a particular focus on these systems and we will adopt the objectives above in that work. In addition, we have a third objective specifically relevant to NGSO satellite systems:

a) 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.

We have prioritised work areas where our actions can have the greatest benefit

4.5 We aim to achieve the above objectives for the entire space sector. However, it is beneficial to prioritise our spectrum management efforts so that they can have the greatest benefit.

4.6 To enable this we have reviewed the priority of our work in the five areas outlined below.

Communications

The delivery of improved satellite services to places that are difficult to reach by fixed or mobile connections.

- Connectivity for remote locations, including consumer broadband, backhaul for mobile base stations
- Connectivity for planes and boats

Earth observation and navigation

Enabling geo-spatial services. This includes:

- Monitoring of the Earth from space in order to inform weather forecasting, understanding of climate and provide satellite imagery (Earth observation)
- Global positioning, navigation and timing.

Understanding and enabling access to space

Enabling safe access to space, understanding of objects in space, as well as understanding the space environment.

- Space launch, safe use of space
- Space weather monitoring
- Study of the solar system and universe

Broadcasting

Satellite TV and TV production using satellites

- Satellite TV direct to consumers
- Video distribution and contribution (e.g. satellite news gathering)

Emergency and disaster relief

Use of satellites by emergency services and in response to natural disasters

- Emergency communication for aero and maritime users
- Satellite communication during disasters when terrestrial networks are unavailable

4.7 We have taken account of several factors when considering how to prioritise our work.

- The consumer and social benefit each area delivers: each area delivers very different types of benefits for UK people and businesses, which are not easily compared, so this is not a decisive factor on its own.
- Market evolution: some areas of the space sector are undergoing profound changes that are important to consider in our strategy; other areas are relatively static.
- Spectrum changes: demand for spectrum may be changing significantly in some areas, while others may be experiencing limited change.
- Regulation: We are more likely to prioritise areas where regulatory changes may be necessary to enable better outcomes.

4.8 Taking account of these factors and our understanding of the sector, including the sectoral trends described in section 3, our view on which areas to focus on is as follows:

i) We propose to prioritise the **Communications** area as it is undergoing significant change and creating new spectrum management challenges. The size of the communications sector is increasing, both in terms of the number of satellites and the number of new players. Some major new players are building NGSO systems comprising of hundreds or thousands of satellites. NGSO satellite systems are making more dynamic and intense use of spectrum, creating challenges to managing interference and regulatory issues internationally.

ii) We consider we should focus on the **Earth observation and navigation** area. This is because the data from satellite Earth observation provides many benefits to different sectors, such as agriculture, the emergency services, climate monitoring and weather forecasting. This is especially important as the threat posed by global warming has become a priority in the UK and internationally. The sector is experiencing modest growth, e.g. new scientific satellites have been developed to improve data on climate change.

iii) The last area we propose to prioritise is **Understanding and enabling access to space**. A large number of satellites are being built, which is driving demand for commercial launches. Some users in this area ensure that space can be accessed safely, e.g. by managing space debris and monitoring space weather. Others improve our understanding of space through radio astronomy and space research.

iv) We do not intend to prioritise satellite **Broadcasting** in this strategy, because whilst satellite broadcasting services deliver valuable TV content to consumers, there is currently no demand for additional spectrum for satellite broadcasting nor any significant changes in its spectrum use.

v) Finally, we propose not to focus on spectrum management changes for **Emergency and disaster relief**. This area provides vital support in the form of emergency distress beacons and temporary communications during disasters or conflict. However, satellite systems providing these services already have the spectrum needed for their operation and we foresee few regulatory changes being needed at this time.

4.9 In addition to the sectoral work areas identified above, we also think it is important to consider cross-cutting activities that support our spectrum management strategy.

4.10 Those parts of the sector outside these prioritised areas will still form part of our work and we will continue to support them via our ongoing activities as described in section 2.

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

5. Work areas and actions

5.1 This section sets out the individual actions in each of our three work areas:

1) Communications (excluding NGSO specific issues which are dealt with in section 6);
2) Earth observation and navigation; and
3) Understanding and enabling access to space.

5.2 Actions in each work area fall into one of two categories:

- **Spectrum access**: Considering new/improved spectrum access for the space sector. Actions in this category aim to enable growth in the benefits that the space sector delivers for UK people and businesses; and
- **Efficient use, sharing and assurance**: Promoting greater spectrum sharing by/within the space sector and assuring continued spectrum access for space sector. Actions in this category aim for spectrum to be used efficiently by space users and not create undue constraints on the growth of other users (i.e. other space users and non-space spectrum users).

5.3 In addition to the three sectoral work areas, we have also identified cross-cutting actions to embed our spectrum management strategy. We set these out at the end of this section.

5.4 The actions we set out are for a 2 – 4 year timeframe. At this stage we have not, in most cases, identified the sequencing or timing of these actions, but welcome any evidence from stakeholders that would inform this.

Work area 1: Communications

5.5 Consistent with Ofcom's overall mission of making communications work for everyone, we will seek to enable the delivery of improved satellite services to places that are difficult to reach by fixed or mobile connections. In particular, we are seeking to enable better broadband options for residential consumers and businesses in such locations, recognising that broadband demand continues to grow.[43] We are also seeking to enable:

i) better broadband connectivity (e.g. Wi-Fi) for passengers on aircraft and on ships;

ii) better mobile coverage, e.g. where satellites could have a role in providing backhaul for mobile base stations in the most remote locations; and

iii) IoT services via satellite, e.g. in remote locations.

5.6 Issues and actions that specifically relate to NGSO satellite communication are set out in section 6. Below, we consider our broader work on satellite communications that is relevant to both GSO and NGSO systems.

[43] Our Connected Nations 2021 report indicates that monthly data use has continued to grow. The figure is now 453 GB per connection (429 GB in the previous year).

Spectrum access for communications

5.7 We are proposing to consider additional spectrum access that could provide greater bandwidth for user terminals (14.25 – 14.5 GHz), gateways (Q and V bands), and Earth Stations in Motion (for aircraft and ship connectivity). We will monitor developments in satellite communications directly to/from unmodified mobile handsets.

5.8 We separately note that there are four guard bands in Ka band which are currently not authorised for satellite earth station (or other) use. [44] We would be interested to understand if there is stakeholder demand for access to these.

Develop proposals for future use of the band 14.25 – 14.50 GHz

5.9 In our 2017 strategy we noted that the Ku band uplink at 14.25 – 14.5 GHz could be used more efficiently. This band is already available for satellite gateway uplinks (permanent earth stations) and transportable earth stations, but not for satellite user terminals. It is also used by radio astronomy and fixed links.

5.10 We are currently exploring demand for additional access to 14.25 – 14.50 GHz and examining options for its future use. At this stage, we consider this a high priority action and we expect to consult on our proposals in Spring 2022. The potential benefits for satellite services from greater access to this band would be a doubling of uplink capacity of Ku band user terminals. This could enable improved services for a range of applications provided by both GSO and NGSO systems, such as inflight broadband and consumer satellite broadband services.

Develop our approach to licensing gateway earth stations in Q/V bands and higher frequencies

5.11 Future satellites are planning to use the bands 37.5 – 42.5, 47.2 – 50.2, 50.4 – 51.4 GHz for feeder links. Some of this spectrum (40.5 – 43.5 GHz) was allocated via auction in 2008 and so access for use of this spectrum for feeder links would be via a commercial arrangement with the existing licensees.

5.12 Authorisation to use other spectrum would be a decision for Ofcom and we plan to develop our approach to licensing satellite earth stations in these bands. In doing so, we will need to take account of other users and future demand for this band. In particular, the 40 GHz band has been identified for mobile and as a future 5G band in Europe.

5.13 In our advice to Government, we also noted that 39-40 GHz might be a good candidate for spectrum to improve rail passenger connectivity. [45] As we develop our approach to licensing gateways in Q and V bands, we will also need to take account of the potential for these frequencies to be put to this use.

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[44] There are four guard bands of 28 MHz located between 28 GHz and 29.5 GHz. These were originally introduced to facilitate deployment of broadband fixed wireless access but may not be needed at specific earth station sites when adjacent bands are both being used to provide satellite uplinks.

[45] Advice to Government on spectrum suitable for improving rail passenger access to data services – Update June 2020 (ofcom.org.uk)

5.14 We understand that some satellite operators are also considering feeder links in higher frequencies, including E-band (80-86GHz), and would welcome further evidence from stakeholders on this.

Additional capacity for "Earth Stations in Motion" (ESIM)

5.15 ESIMs provide satellite connectivity to moving platforms, including on ships, aircraft and vehicles. As we said in section 3, use of ESIMs on aircraft and ships is increasing. These services typically make use of portions of the Ku and Ka bands.

5.16 We plan to consider updates to ship, aeronautical and network licences for ESIMs in Ku and Ka bands.

- **14.25 – 14.5 GHz:** As discussed above we propose to look at future uses of the 14.25 – 14.5 GHz band. As part of this we may consider extending our licences to allow ESIMs in this band, including any necessary measures to ensure coexistence with other users.
- **27.5 – 30 GHz:** We will also review the existing arrangements for ESIMs in the 27.5 – 30 GHz band, with a view to extending our authorisations to a larger range of frequencies within the band. There may be some scope to allow ship and aircraft ESIMs to make more use of the band without causing interference to users of Spectrum Access licences. However, at present, it may not be possible to extend use of the band by land based ESIMs because of the difficulties in coexisting alongside users of Spectrum Access licences.

5.17 WRC-23 Agenda Item 1.15 is studying ESIM communicating with GSO satellites in 12.75 – 13.25 GHz. We will monitor and, as appropriate, engage with these issues. ESIM issues which are specific to NGSO satellite systems are discussed in section 6.

Communications directly to/from mobile handsets and other terrestrial devices

5.18 In section 3, we referred to the possibility of standard mobile phones or other terrestrial devices (e.g. Internet of Things terminals) being able to connect to satellite services when out of range of terrestrial base stations. We are supportive in principle of innovations which extend the coverage of terrestrial services but note some of these satellite services would seek to transmit from space in bands currently used by mobile operators or by licence exempt equipment in the UK – and using frequencies where there is no internationally agreed satellite allocation.

5.19 Our preference is for satellite services to transmit in satellite allocated frequencies. Where there is no satellite allocation, sharing mechanisms between satellite and terrestrial service should be explored to ensure that satellite services do not cause interference to terrestrial users.

5.20 Because technology remains at an early stage, we plan to monitor developments in this area to understand the potential for sharing between satellite and mobile and the potential benefit for UK users from such services.

International allocations for Mobile Satellite Services (MSS)

5.21 Agenda item 1.18 for WRC-23 is considering possible identification of new allocations for the future development of narrowband mobile-satellite systems. These allocations could be suitable for 'Internet of Things' applications. At present, we are not aware of UK demand for these additional allocations and are not persuaded that identifying additional frequencies should be a high priority. However, we will monitor this work and take its conclusions into account in our national authorisation work as appropriate.

Efficient use, sharing and assurance for communications

Protection criteria for Fixed Satellite Services (FSS)

5.22 A crucial piece of information when assessing the potential of two services to coexist is how much interference each of them should be expected to accept from the other. There are international recommendations on such protection criteria for the Fixed Satellite Service[46], and they are used when determining how services like terrestrial fixed or mobile should protect the FSS. These recommendations on protection criteria have not been reviewed in decades, but in the meantime the sharing environment has changed. [47]

5.23 ITU Working Party 4A has recently discussed the possibility of updating these recommendations. We agree that there is value in doing this and we will work towards proposing protection criteria that ensures the continued provision of fixed-satellite services while not constraining unnecessarily the introduction of new services in the same bands.

[46] See ITU-R S.1432: "Apportionment of the allowable error performance degradations to fixed-satellite service (FSS) hypothetical reference digital paths arising from time invariant interference for systems operating below 30 GHz".
[47] For example, the FSS shares frequencies with the mobile service more frequently, meaning it is subject to a time-varying interference that may not be properly accounted for in the existing recommendations. As another example, there are increasingly more adaptive digital links in the FSS, as opposed to older analogue links, and their tolerance to interference is likely very different.

Table 1: Actions in work area 1: Communications

Issue	Action
Spectrum access	
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.
Efficient use, sharing and assurance	
Protection criteria for FSS	Support work in ITU Working Party 4A to review recommendations on FSS protection criteria.

Work area 2: Earth observation and navigation

5.24 The Earth observation community uses parts of the radio spectrum for sensing natural phenomena (e.g. detecting water, oxygen and carbon dioxide in the atmosphere or the thickness of ice in polar regions). For 'passive' sensing[48] the bands used are determined by physics which means that there is little choice about the frequencies used. Radio frequencies are also used to transfer measurement data and imagery taken by satellites

[48] Passive earth sensing is the use of receive-only sensors on satellites to monitor naturally occurring radio emissions created by the physical characteristics of Earth and its atmosphere. Active earth sensing is where satellites transmit radio waves and then listen to the reflections that bounce back from the Earth.

back to the ground. Information and insights provided by Earth observation data benefits UK citizens and consumers in several ways. It can support, for example, weather forecasting, more efficient public services, new commercial applications, and more informed policy making (such as, in relation to climate change).

5.25 Satellite based position, navigation and timing (PNT) systems (such as GPS)[49] are extremely important for people and businesses in the UK, providing positioning information, helping us to navigate wherever we are in the world and providing highly accurate timing for some critical services.[50]

5.26 Ensuring reliable access to Earth observation and space-based PNT information is therefore important for almost everyone living in the UK today. Our actions relate to both spectrum access and sharing and assurance for these services. We set these out separately below.

Spectrum access for Earth observation and navigation

5.27 Our actions to support spectrum access for Earth observation include:

- considering appropriate protection for sites in the UK used for downlinking data from Earth observation satellites (in 8 GHz and 26 GHz bands);
- engaging in international work to consider additional bands that could be used for transferring data between Earth observation and other satellites; and
- supporting international consideration of spectrum access for climate and weather measurements.

5.28 We will also work with government to understand if there are any new spectrum requirements to support satellite based or terrestrial PNT back-up systems.

Protection of downlink sites for Earth observation data

5.29 The amount of data that is generated by Earth observation satellites is likely to increase, potentially leading to increased demand for access to spectrum used for downlink data. However, this could be offset by the use of optical links, which can transmit larger quantities of data; onboard imagery processing and AI may also reduce the requirement for data transfer.

5.30 Two key bands for Earth observation downlink are 8 GHz and 26 GHz. Our approach for each of these spectrum bands is set out below.

26 GHz

5.31 There is an international allocation for Earth Exploration Satellite Services (EESS) at 25.5 – 27 GHz for data downlinks (as opposed to making measurements). We currently offer RSA in 25.5 – 26.5 GHz, for receive only earth station sites. This means that these earth stations

[49] Satellite-based PNT services such as the GPS, Beidou, Glonass and Galileo constellations are collectively known as "Global Navigation satellite Services" or GNSS. We will continue to use PNT in this document as we will refer to both satellite and terrestrial services.

[50] The Blackett Report into Satellite Derived Position and Timing outlined the UK's dependence on satellite-based PNT and recommended a number of measures to make critical services more resilient to disruption or loss of these services.

can be taken into account when making new assignments for other services in the band. The frequency band 26.5 – 27 GHz is currently administered by the MoD for military use.

5.32 We understand from engagement with stakeholders that there may be benefits from Earth observation using the additional 500 MHz (26.5 – 27 GHz) under the international EESS allocation that is not currently protected by RSA. We would be open to considering extending RSA to this band, taking account of future 5G authorisations and MoD use in the band, if there was clear evidence of these benefits. We would welcome evidence from stakeholders on demand for use of this spectrum.

5.33 The 24.25 – 27.5 GHz band (which includes the EESS downlink allocation) has been identified as a pioneer band for 5G. We will be consulting on proposals to make this band available for 5G and other wireless broadband services in Q1 2022/23. This includes how we might accommodate existing and future use of this spectrum for Earth observation, as well as continued use by the MoD.

8 GHz

5.34 The 8 GHz band is currently used by a small number of ROES in the UK to receive data from Earth observation satellites and we recognise that use of this band is growing. In addition, the band is used by the MoD for military applications and fixed links are used in the south east of the UK.[51]

5.35 As fixed links start to be used over a wider area[52], we may need to consider what need there is to protect existing Earth observation ROES sites from interference (e.g. via an RSA). We expect that new sites located outside this area will be unlikely to be impacted by fixed links, although there will be some MoD use in a few locations. We therefore encourage any new ROES sites to be established further north and believe this should meet the needs of users downlinking data from polar orbiting Earth observation satellites.

5.36 We would welcome any evidence from stakeholders on the future demand for 8 GHz ROES sites across the UK and will consider the need for any additional protection of ROES sites in light of this and growing fixed link use.

Consideration of inter-satellite links

5.37 Inter-satellite links are used among other things to transfer data between non-geostationary Earth observation satellites and geostationary relay satellites that are then able to transmit the data to the required point on Earth. This way there is no need to wait until the observation satellite is visible from the required point on Earth, and data is made available much more quickly.

5.38 There are already some allocations for these inter-satellite links, e.g. 24.45 – 27.5 GHz. Additionally, the possibility of operating inter-satellite links in other bands is being considered under WRC-23 Agenda Item 1.17. If feasible, such links would be operated under existing FSS allocations in Ka band.

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[51] Opening of 8 GHz for civil users: Guidance for applicants (ofcom.org.uk)

[52] An area south of a line broadly transecting the Severn and Blackwater Estuaries.

5.39 We believe these new inter-satellite links could make connectivity easier for small satellites and non-GSO satellites in general, and we will continue to engage in the international work. At the same time, we need to ensure appropriate protection of existing UK services, and we think that this new application should not place any additional constraints to them.

5.40 Additionally, satellite operators are starting to adopt optical frequencies for inter-satellite links.[53] Optical links are not regulated by the Radio Regulations and our spectrum management power do not currently extend to optical frequencies.[54] However, the use of such links could ease congestion in some of the frequency bands we manage and/or reduce demand for earth stations in the UK, so we plan to monitor developments in this area.

Spectrum access for climate change monitoring and weather forecasting

5.41 To enhance climate change monitoring and weather forecasting capabilities we will support WRC-23 AI 1.12 regarding a new allocation for active EESS around 45 MHz and AI 1.14 on review of existing EESS (passive) allocations and possible new allocations in the band 231.5 – 252GHz. We will engage with international work on these WRC-23 agenda items with the aim of achieving appropriate spectrum access for Earth observation without placing undue constraints on other users.

Spectrum requirements to support resilient positioning, navigation and timing

5.42 The Government's National Space Strategy stated that the 'government is evaluating the case for investing in resilient Position Navigation and Timing capabilities through a mix of innovative new terrestrial and space-based technologies'. The UK Space Agency launched a satellite based PNT programme in late 2020 to explore new ways of delivering satellite navigation and timing services to the UK from space. We will work with government to understand potential spectrum requirements and assess what support may be necessary for this work.

Efficient use, sharing and assurance for Earth observation and navigation

Ongoing protection of spectrum used for Earth observation measurements

5.43 The key issue for Earth observation applications that rely on spectrum for active or passive sensing is how predictable spectrum access will be over the long-term.[55] We recognise the importance of ensuring long-term predictability of access to spectrum bands used for sensing. We will consider Earth observation uses of spectrum when introducing new services and will engage internationally to promote a balanced approach.

[53] Operating at much higher frequencies than radio frequencies, these links can transfer much higher volumes of data and reduce the need for Gateway Earth Stations. For satellite communications networks, they can provide very low latency connections relative to fibre over long distances due to the fact that light travels faster in free space.
[54] Ofcom's spectrum management functions under the WT Act concern frequencies up to 3,000 GHz (3 THz) and visible light frequencies fall above this limit.
[55] This is especially important for passive sensing (e.g. radio astronomy or monitoring soil moisture) which depends on access to bands that are determined by specific natural phenomena.

5.44 Nonetheless, an overly conservative protection of spectrum used for observing natural phenomena can significantly constrain the development of new communication services (e.g. 5G and future services using terahertz bands). We will balance the needs of Earth observation with the needs of communication services by applying the principles for promoting spectrum sharing, as set out in our spectrum management strategy. This will include considering the real performance of systems rather than the theoretical worst cases when assessing the risk of interference.

5.45 One specific example is our work in preparing to authorise access to the 26 GHz (24.25 – 27.5 GHz) band for future outdoor wireless broadband services, where we are consulting on measures for appropriate protection of spectrum used for Earth observation measurements, as well as radio astronomy (see paragraph 5.65 below).

Updates to the ITU Recommendation dealing with Earth observation sensors

5.46 One specific action to support the aims outlined above, is to propose updates to the relevant ITU-R Recommendation dealing with EESS system characteristics.[56] We think it is important that this captures information on the selectivity of EESS receivers and that it is kept up-to-date to reflect real systems in use. This will help ensure that sharing studies consider the real performance of such systems. We also plan to use this work to highlight that the Radio Regulations do not protect these receivers from emissions outside their allocated bands.

Efficient use of S-band for TT&C

5.47 We recognise the need for S-band (2205 – 2210 MHz uplink and 2200 – 2290 MHz downlink) to be protected for TT&C and understand there are increasing demands for TT&C.

5.48 However, we are seeing an increase in satellite fillings that cover the whole of these bands, which is increasing the difficulty of coordinating TT&C use. We will continue to engage in ITU-R work to find a solution through development of a new Recommendation on the optimal use of the S-band.

Resilience of existing positioning, navigation and timing systems

5.49 Satellite-based PNT receivers may experience interference from out-of-band signals (signals from other uses outside the band in which they are receiving) or in-band interference from jammers. There is a clear distinction in our approach to these issues.

5.50 Our general position on out-of-band interference (as reiterated in our spectrum management strategy) is that we will not normally expect to take action on interference if receivers are impacted by signals outside the band in which they are receiving. We

[56] RS.1861 - Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz.

therefore encourage manufacturers to use more robust PNT receivers where available and note that standards work[57] could improve the robustness of future receivers.

5.51 Causing deliberate in-band interference to PNT services using a jammer is a criminal offence and it is also a criminal offence to make jammers commercially available in the UK[58] . Our ongoing compliance work in relation to such issues is set out at paragraph 2.43.

[57] IEEE SA - IEEE 4003-2021

[58] Under section 68(1) of the Wireless Telegraphy Act 2006 (legislation.gov.uk), it is a criminal offence to cause deliberate interference to wireless services.

Table 2: Actions in work area 2: Earth observation and navigation

Issue	Actions
Spectrum access	
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.
Efficient use, sharing and assurance	
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.

Work area 3: Understanding and enabling access to space

5.52 The growth in satellite communications and Earth observation, fuelled by the development of smaller satellites and deployment of large NGSO constellations, depends on a range of activities that support and enable access to space. These activities include space launch

and managing the safe use of space, for example through in-orbit servicing, debris tracking and removal. Demand for these activities is growing and each of them may have spectrum requirements of their own.

5.53 A further activity that is vital to support use of space, as well managing risks to infrastructure on Earth, is the monitoring of space weather. Space weather refers to the physical conditions in the space environment, such as dangerous solar flares. Severe space weather events can have potentially significant impacts on the UK's critical national infrastructures i.e. national power grid, critical communication systems, as well as potential disruptions to air/rail/road travel.[59] Predicting space weather therefore is crucial for satellite operators, power companies, aviation industry and space agencies. Early warnings allow mitigating actions to be taken to prevent harmful incidents such as power grid failures and damage to satellites. The Met Office Space Weather Operations Centre in the UK is one of three space weather prediction centres around the globe.

5.54 Radio astronomy and space research are other important activities that improve our understanding of space and the evolution of the universe. The UK hosts renowned radio astronomy sites at Jodrell Bank and Mullard observatories and has significant investment in the SKA[60] which is headquartered in the UK.

Spectrum access for understanding and enabling access to space

5.55 In some cases, the need for spectrum for activities that support access to space is clear and immediate – we set out our work on space weather and space launch below. In other cases, such as sub-orbital vehicles and supporting the safe use of space, spectrum requirements are still emerging.

International regulatory framework for space weather

5.56 Currently, space weather sensors operate under allocations for other services and have no recognition in the Radio Regulations for its spectrum use. We recognise the importance of regulatory certainty for space weather spectrum access, to support vital monitoring and prediction activities (discussed above). We are therefore leading development of CEPT policy for WRC-23 agenda item 9.1.A. which aims to develop the international regulatory framework for space weather, and we intend to continue this work.

Spectrum authorisations for UK space launch

5.57 The UK's northerly position means it is well-suited as a location from which to launch satellites into polar orbits. This orbit is used by Earth observation missions and other small satellite services. The UK's Spaceflight Programme aims to establish commercial vertical

[59] Space weather is included on the UK's national risk register: CCS's National Risk Register 2020 (publishing.service.gov.uk)
[60] The SKA is an intergovernmental project to build the world's most powerful radio astronomy facilities in Australia and South Africa.

and horizontal small satellite launch from UK spaceports from 2022 to support the UK's growing small satellite community.[61]

5.58 To support these aims, we have examined the spectrum authorisations needed for spaceflight from the UK and have assessed that these can be managed through our existing processes. More information can be found on our space launch web page. Some frequencies and the timing of launch may need to be coordinated with the Ministry of Defence, Met Office and other government agencies. As a consequence, we encourage all operators to engage with us early.

Sub-orbital vehicles

5.59 In addition to the traditional launch services above, there is growing interest in the use of sub-orbital vehicles both for research and space tourism purposes. These are flights to the edge of space (~100km) lasting a few minutes. For each launch, air traffic controllers must clear the airspace, requiring aircraft to reroute around the segregated airspace where they operate. As the number of launches and sub-orbital missions increases, this could become both disruptive and costly for airlines.

5.60 Working with other interested UK parties, such as the UK Space Agency and the CAA, we are supportive of efforts to create an international framework for communications to and from sub-orbital vehicles under Agenda Item 1.6 of WRC-23.

Safe use of space

5.61 Given the rapidly rising numbers of space objects and proposals for mega-constellations, there are growing concerns across the space community about the potential for space debris and the need to ensure safety over the longer-term access to space. 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. Ofcom, as the communications regulator, does not have direct responsibilities for these issues. However, we recognise the role spectrum will play in enabling safe use of space.

5.62 We plan, therefore, to consider appropriate access to spectrum for radars to track the movements of objects in space. We also want to understand (e.g. through informal discussions with other administrations and space agencies) whether changes to international spectrum allocations are needed to support in-orbit servicing and other safe space initiatives.

5.63 Conversely, we recognise that physical risks to satellites from space debris etc. could ultimately impact the provision of space-based services (e.g. positioning and broadband) for UK users. We will discuss with our counterparts in the CAA and the UK Space Agency how we can work together on this issue.

[61] How we are promoting spaceflight from the UK - GOV.UK (www.gov.uk)

Efficient use, sharing and assurance for understanding and enabling access to space

Protection of spectrum for radio astronomy measurements

5.64 Radio astronomy depends on being able to take measurements, at extremely low signal levels, of phenomena across the universe, and so operates in bands which are allocated for that specific use to avoid any radio interference from other users. In addition, the very sensitive receivers used makes them susceptible to out-of-band emissions.

5.65 To enable ongoing radio astronomy measurements, specific actions we are proposing to take are:

- As discussed above, 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.[62]
- We outline proposals in section 6, in relation to NGSO systems, to consider new licence conditions to ensure protection of radio astronomy and to work closely with stakeholders on a new approach to handling NGSO satellite interference to radio astronomy.

5.66 In addition, we will engage in CEPT and ITU work on development of appropriate solutions for protection of radio astronomy sites in the UK and abroad (SKA) from satellite emissions.

[62] This is the subject of a separate consultation, see: Protecting passive services at 23.6-24 GHz from future 26 GHz uses (ofcom.org.uk).

Table 3: Actions in work area 3: Understanding and enabling access to space

Issue	Actions
Spectrum access	
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.
Efficient use, sharing and assurance	
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.

Cross-cutting actions to embed our spectrum management strategy

5.67 Our overall spectrum management strategy is reflected in the work identified above for each work area. In addition, we have also identified three cross-cutting actions to take forward our spectrum management strategy that are relevant to multiple areas. These actions flow from our strategic focus on supporting wireless innovation, particularly to identify 'spectrum for pioneers', and on promoting spectrum sharing.

Supporting wireless innovation: spectrum for space pioneers

5.68 A key area of increased focus for our spectrum management strategy is to support wireless innovation by making it even easier for a broad range of users to access spectrum. We already deal with a wide range of innovative players and projects in the space sector whose authorisation requirements do not always fall neatly within one of our existing licence products. This is for a variety of reasons, including because the project is a one-off with bespoke requirements. Often these are for TT&C for small satellites or 'cubesats', which tend to use lower frequencies and bands that are not as well-established as those used by traditional (larger) satellites. These satellites are often developed by UK-based universities or small satellite manufacturers. However, the use of less established bands means the authorisation options and complexities of constraints for use are not always well understood.

5.69 Therefore, to further support innovation in the space sector we plan to identify a number of frequency and authorisation options that may be relevant for new cubesat/small sat applications (particularly but not limited to TT&C), particularly those where we are aware of demand for those. We will aim to clarify regulatory constraints associated with these options and communicate this as clearly as possible to a wide audience through our website and our stakeholder engagement activities, including with universities and start-ups (see below). We will provide further information about the process for applying for licences for such bands and in parallel streamline (where possible) our processes for assessing and granting such licences.

Promoting spectrum sharing: Greater use of network licences

5.70 One of our strategic aims is to promote spectrum sharing, particularly by encouraging spectrum users to be good spectrum neighbours, and to achieve that whilst providing appropriate assurances for continued use of spectrum. We think that some changes in the way certain equipment is authorised could support that aim.

5.71 At present, there are certain types of equipment that can be used in the UK to communicate with a satellite without the need for a licence, i.e. because it has been exempted from licensing. This includes MSS terminals and some FSS terminals. In addition, as discussed, some satellites operators are seeking to develop systems that communicate with exempt devices in bands allocated to terrestrial services.

5.72 Although exemption from licensing has benefits, and under certain conditions we are required to exempt, it can also create issues for the regulation of spectrum sharing, in particular our ability to effectively deal with unanticipated harmful interference.[63]

5.73 Resolution of harmful interference may be expedited where the use of equipment is authorised under the terms of a licence where details of the licence-holder are known (as

[63] s8(4) of the WT Act requires us to exempt if certain conditions are met. The grounds not to exempt are interference, impact on the technical quality of service or inhibiting the development of effective arrangements for the sharing of frequencies.

contrasted to exempt devices, where no information is recorded on who is responsible for the device). A licencing regime also allows Ofcom to use its powers[64] to impose substantial financial penalties for transgressions of licence conditions, including those intended to regulate spectrum sharing, which in turn can create greater incentives for compliance with those conditions.

5.74 In addition, an exemption regime lacks the agility of a licencing regime where, for example, new enhanced schemes for sharing can be implemented sooner than amending an exemption regime. The latter may take many years to implement as a result of having to accommodate a transition period to replace equipment and alert users who cannot be easily identified.

5.75 An alternative which avoids these limitations and supports the development of spectrum sharing (and without creating significant barriers to use), is to authorise via network licences. These are "light" licences that typically authorise an unlimited number of terminals. A single network licence can be held by a satellite operator, without individual users needing to apply for or hold an individual licence for their equipment. We will therefore consider greater use of network licences in the space sector, including the possibility of removing existing exemptions and transitioning to network licences. We would consult on specific proposals to make such changes.

Promoting spectrum sharing: Conditions on satellite downlinks

5.76 In some spectrum sharing scenarios there can be a concern about the potential for signals transmitted by a satellite, i.e. space to Earth downlinks, to cause harmful interference to spectrum users located in the UK. This might include satellites transmitting into the UK in bands which are not allocated to satellite services (also see paragraphs 5.18-5.20 above).

5.77 These satellites will need to operate in accordance with the Radio Regulations, and if we believe they are not and hence causing harmful interference in the UK, we can raise this with the administration responsible for the relevant satellite filing. However, this does not give us direct ability to act to resolve problems affecting UK users.

5.78 In most cases (i.e. whenever the satellite is providing a service in the UK), equipment communicating to these satellites will be authorised under the WT Act. Therefore, to provide greater ability to manage sharing between satellite downlinks and other UK spectrum users, we plan to consider, where relevant and appropriate, additional conditions on UK authorised equipment. These would place relevant requirements on transmissions from the corresponding satellite, such as compliance with specific conditions in the Radio Regulations. One specific example discussed in section 6 relates to NGSO satellite downlinks sharing with radio astronomy services.

[64] Included in section 42 of the WT Act.

5.79 Such an approach would be dependent on the entity holding the UK licence also having some control over the satellite transmissions (this is an issue which we have previously considered in our NGSO licensing updates).

Table 4: Cross-cutting actions embedding our spectrum management strategy

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.

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?

6. NGSO satellite communications

6.1 In the previous section we set out our work in three areas, including our work on satellite communications that is relevant to both GSO and NGSO satellite communication systems. This section specifically considers NGSO satellite communication systems and the opportunities and challenges which are unique to them. As discussed in section 3, the growth of NGSO satellite systems is one of the most significant developments in the space sector, offering improved satellite communication services, but also presenting particular challenges from a spectrum management perspective.

6.2 This section focuses on the large-scale deployment of NGSO communication systems in bands allocated to the FSS) (usually above 3 GHz and typically offering wide bandwidths necessary for high-capacity services), as this is where we see the greatest growth and emergence of spectrum management challenges. We recently updated our approach to licensing these NGSO systems, particularly to manage the risk of interference between different NGSO satellite systems and to help safeguard competition.[65] Here, we consider the wider and longer-term implications of NGSO systems, including the international framework for NGSO systems and coexistence between NGSO systems and other spectrum users.

6.3 We also consider the implications of the more modest growth in MSS NGSO services in bands below 1 GHz. We do not consider other satellite applications, including Earth observation and navigation, that use satellites in non-geostationary orbits, as these are not being deployed to the same scale or creating significant new spectrum management challenges.

6.4 The structure of this section is as follows:

- We describe the role that new NGSO satellite systems satellites could play in improving communications services in the future.
- We identify the potential broader and longer term challenges that NGSO systems pose from a spectrum management perspective.
- We set out our proposed approach to FSS NGSO communication systems, including actions relating to:

  i) Spectrum access for NGSO satellite systems.

  ii) Efficient use and assurance for a range of spectrum sharing scenarios: NGSO systems sharing with other NGSO systems; NGSO systems sharing with GSO systems; NGSO downlinks sharing with radio astronomy and NGSO systems sharing with terrestrial users.

6.5 We also briefly discuss our approach and actions in relation to MSS NGSO communications systems operating below 1 GHz.

[65] Non-geostationary satellite systems - Licensing updates (December 2021)

New NGSO satellite deployments could benefit consumers

6.6 As discussed in section 3, new NGSO mega-constellations offer benefits over existing GSO systems. They are closer to Earth, meaning they have lower latency. Meanwhile, the large numbers of satellites mean that the network as a whole is likely to have greater capacity and higher speeds. These features are all important advantages for broadband delivered via NGSO network and make an NGSO broadband experience more similar to the experience of users on a fixed terrestrial broadband network. We support these innovative systems and want to enable as many of them as possible, to provide services and increase choice for people and businesses in the UK.

6.7 Nonetheless, NGSO systems may still have some limitations. For example, to maintain a reliable connection to NGSO service, users may need to locate their satellite dish so that it has a sufficiently clear view across to the sky without obstructions.[66].

6.8 Table 5 below sets out some of the commercial NGSO systems currently being deployed or planned based on publicly available documentation. We have limited ourselves here to the largest constellations that are either launching or plan to launch services in the next 2-3 years and could serve consumers in the UK but recognise that a number of other constellations are being planned. For example, both China[67] and the EU[68] have announced plans for NGSO constellations; operators for these constellations may not provide a service in the UK but would need to work with other operators to ensure both services could coexist.

[66] See for example the information provided on the Starlink Webpage at: Help Center (starlink.com).
[67] China establishes company to build satellite broadband megaconstellation - SpaceNews
[68] Speech by Commissioner Thierry Breton at the 13th European Space Conference | European Commission (europa.eu)

Table 5: Commercial NGSO systems

Satellite System	Spectrum for gateways	Spectrum for user links	Initial No. satellites (1st Gen)[69]	Altitude (km)	Latency (ms)[70]	Coverage (latitude)	Type of service
Amazon[71]	Ka band[72]	Ka band	3236	590 610 630	~30	57N-56S	Direct to home broadband[73]
Kepler[74]	Ku band[75]	Ku band	140	575	20-40	Global	Internet of things
OneWeb[76]	Ka band	Ku band	648[77]	1100-1200	50	Global	Backhaul[78] /mobility[79]
SpaceX[80]	Ka band	Ku band	4408	540 550 570	20-40	Global	Direct to home broadband
Telesat[81]	Ka band	Ka band	298	1015 1325	50	Global	Backhaul / mobility

However, NGSO systems also create challenges

6.9 NGSO satellite systems comprising large numbers of satellites make use of spectrum in a more intensive and dynamic way than existing GSO satellites. If operators' plans come to fruition there will be thousands of NGSO satellites in key bands (such as Ku and Ka bands) constantly moving across the sky, compared to the few hundred existing GSO satellites. As discussed in our consultation on updates to our NGSO licensing, NGSO satellite

[69] Designs for 1st generation architecture for these constellations are more certain. More satellites are expected for all these constellations and are indicated in the FCC references below. These may evolve.
[70] The latency figures are estimates based on the height of each constellation and the speed of light.
[71] FCC Authorizes Kuiper Satellite Constellation | Federal Communications Commission July 30 2020
[72] Ka band satellite services typically use 18-20 GHz for downlink and 27.5-30 GHz for uplink.
[73] Direct to home indicates a broadband service sold direct to consumers.
[74] FCC Grants Kepler Communications Access to US Market | Federal Communications Commission
[75] Ku band satellite services typically use 10.7-12.7 GHz for downlink and 14.0-14.5 GHz for uplink.
[76] FCC Grants OneWeb U.S. Market Access for Expanded NGSO Constellation | Federal Communications Commission
[77] Size of initial OneWeb constellation: OneWeb Completes its 'Five to 50' Mission to Cover Regions North of 50 Degrees Latitude including UK, Canada, Alaska and Arctic Region | OneWeb
[78] Backhaul denotes a service provided to broadband and mobile telecommunications companies, helping them to extend their networks into hard to reach areas. This can sometimes include connectivity for towns and cities.
[79] "Mobility" here denotes a broadband service for air, maritime, rail or road companies, e.g. cruise ships, shipping, airlines.
[80] FCC Ruling on SpaceX Modification, FCC-21-48A1.pdf, April 2021.
[81] Telesat modifies its constellation: 2378318.pdf (fcc.report).

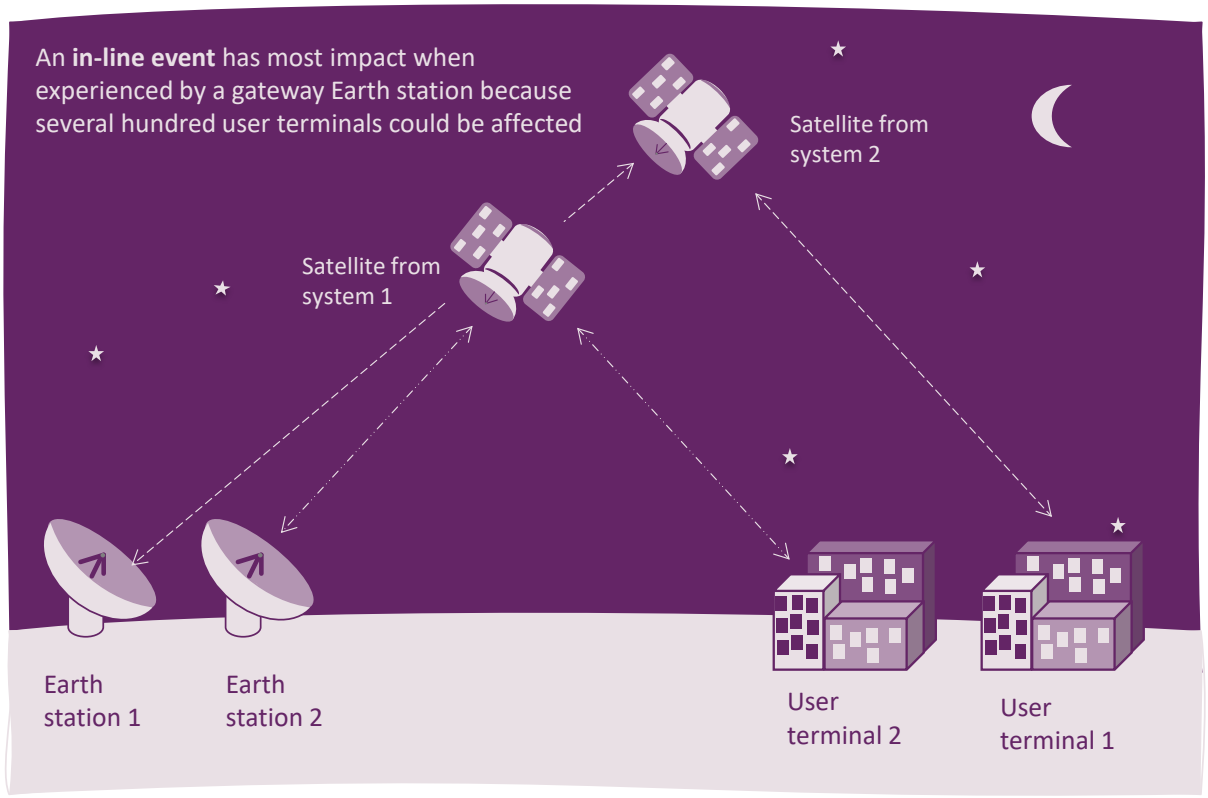
systems raise interrelated interference and competition issues. These challenges could also evolve over time as new NGSO systems are deployed with different architectures and technologies.

Interference challenges

6.10 NGSO satellite systems raise challenges in terms of managing interference between different NGSO systems, risking services to users being disrupted. NGSO systems may also create different interference risks to other spectrum users including GSO satellite systems, radio astronomy users and terrestrial spectrum users. Figure 3 below illustrates one interference scenario (between different NGSO systems and annex 2 explains a range of different NGSO interference scenarios in more detail).

6.11 In response, we aim to promote the efficient sharing of spectrum between these different users, and ensure we have effective mechanisms for dealing with harmful interference if it were to arise.

Figure 3: Example of interference between NGSO systems – an 'in-line event' on the gateway link



Competition challenges

6.12 We want to enable as many NGSO systems as possible, to provide services and increase choice for people and businesses in the UK. However, the complexities of managing interference between NGSO systems could also have implications for competition. One issue could, in principle, be limitations in the availability of sites for gateway earth

stations, if the separation distance required to protect such gateways were very large. As discussed in our NGSO licensing statement, our current starting point is that this competition risk is not material.

6.13 A further concern (discussed below in paragraphs 6.30-6.37) would be if NGSO operators used their ITU regulatory status or early deployment as a means to constrain competitors, leading to a more concentrated global market, and fewer suppliers to UK users than might otherwise be possible. Weaker competition may lead to worse outcomes for consumers, such as higher prices and/or less choice. Our primary approach to tackling this competition concern is to promote – at both national and international levels – efficient spectrum use and spectrum sharing, so as to enable multiple NGSO systems to coexist. In addition, greater access to spectrum may also support competition by enabling NSGO systems to expand their capacity.

Future challenges

6.14 There are several ways in which NGSO systems could evolve in the future, which might have implications for spectrum management, including:

- more countries filing for NGSO systems with the ITU;
- greater numbers of operators deploying systems;
- larger numbers of satellites in some constellations;
- greater densities of gateway earth stations;
- greater use of (optical) inter-satellite links;
- greater use of active antennas onboard satellites and in the terminals;
- a broader range of frequencies including higher frequencies for feeder links;
- additional payloads for other services, e.g. Earth Observation or GNSS; and
- greater use of cloud services and AI for network management.

6.15 Although some of these trends could increase the capacity of networks and the range of services available to UK consumers, they may also change the nature of the challenges outlined above or introduce new challenges in the future. For example:

- International coordination and national spectrum management could be more challenging as more systems are deployed, especially in bands which are common across several NGSO systems, e.g. Ku and Ka band.
- Larger numbers of satellites in some constellations could help avoid interference to/from other operators (see annex 2 for discussion of satellite diversity) but they could also make it harder for new entrants in the future, potentially limiting competition.
- Greater use of active antennas (onboard satellites and in terminals) or other technologies might improve sharing between NGSO systems, and possibly with other wireless services.
- Interference risks between NGSO systems will need to be reduced if they are to be used for safety of life services.

- With more countries filing for NGSO systems, there may be a greater possibility of systems that are not operating services in the UK but could cause interference to – or experience interference from – services in the UK.

Addressing NGSO challenges

6.16 We have already introduced measures to mitigate interference risks between NGSO systems and competition concerns through our new national NGSO licensing process. The rest of his section considers additional measures, that build on that process, but also cover international actions and coexistence with other services. It follows a similar structure as section 5 by considering proposals for:

- **Spectrum access** for NGSO systems – building on the spectrum access actions outlined in section 5; and
- **Efficient use, sharing and assurance** – encouraging NGSO systems to efficiently share spectrum with other users, whilst providing appropriate assurances over spectrum access.

Spectrum access for NGSO systems

6.17 In many cases, the spectrum that is available for use by GSO satellites systems is also available for NGSO use, in line with our technology neutral principles. In addition, in section 5 we set out a number of opportunities where we will consider providing greater spectrum access for satellite systems in general. In doing this we will consider both GSO and NGSO systems, whilst taking into account of any differences in the ability of GSO and NGSO satellite systems to share spectrum with other users. We do not believe there is a need to consider spectrum specifically for NGSO systems, as NGSO systems can generally share with GSO systems and the bands in demand for NGSO systems are also in demand for GSO systems.

6.18 Nonetheless, in the limited cases where spectrum access is currently available for GSO but not NGSO satellite systems, we will consider whether NGSO systems should be able to access the same spectrum in the same way as GSO systems. In considering this, we will take into account whether greater spectrum access will enable improved services for users, and the ability of NGSO systems to share spectrum with other spectrum users. Below, we set out our approach for our national authorisation and international work.

National authorisation

6.19 At present, the following types of authorisation support GSO but not NGSO satellite systems:

- **Transportable Earth Station** – this licence is designed specifically for operation with GSO satellites, including by earth stations used for satellite news gathering. We are not currently aware of demand for these earth stations to operate with NGSO systems, and so at present we are not proposing to extend for NGSO use.

- **Permanent Earth Station** – NGSO use is not available under this licence, however, equivalent spectrum is available under the corresponding non-geostationary earth station licence. Therefore, no further action is needed.

6.20 In addition, the following types of earth station authorisation currently give greater spectrum access for GSO than NGSO satellite systems:

- **Earth station network licence** – we will consider extending this authorisation so that NGSO ship and aircraft earth stations can broadly use the same parts of Ku and Ka band spectrum that are already available for GSO use.
- **Ship and aircraft radio licences** – as well as updating the earth station network licence described above, we would also consider corresponding changes to the ship and aircraft radio licences to allow the installation and operation of NGSO earth stations on board ships and aircraft registered in the UK.

International

6.21 According to the ITU Radio Regulations, almost all of the spectrum allocated for use by GSO FSS systems is also available for use by NGSO systems.

6.22 Going forward, given the growth of NGSO systems, most international work is likely to consider NGSO as well as GSO use. One area where there are regulations limited to GSO use are those regulations related to ESIMs. WRC-23 Agenda Item 1.16 is studying NGSO ESIM use (in bands where there are existing decisions on GSO ESIM). We remain generally supportive of this work provided that incumbent services (e.g. UK fixed links) remain adequately protected, and we will seek appropriate measures incorporated into the Radio Regulations to achieve this.

Efficient use, sharing and assurance

6.23 NGSO systems share spectrum with a range of other spectrum users. We have considered our approach towards each of the follow types of spectrum sharing:

- NGSO systems sharing with other NGSO systems;
- NGSO system sharing with GSO systems;
- NGSO systems sharing with Radio Astronomy; and
- NGSO systems sharing with terrestrial services

6.24 For each type of sharing, we set out our approach at the national level (using our spectrum management powers in the UK) and internationally (through our international engagement in the relevant bodies), in order to improve the efficiency of spectrum use and ability of NGSO systems to share with other users. The technical basis for each type of sharing is outlined in annex 2.

6.25 In addition, we also set out our approach to satellite interference monitoring, to enable us to provide appropriate assurances for continued use of spectrum. Interference to/from new NGSO satellite systems will likely be localised, transient, and varying in time and geographic location. Therefore, we believe a new approach in satellite interference

monitoring will be needed, where measurements are made close to, or at, the site suffering interference (rather than only at a distant monitoring station. As part of this, we plan to conduct lab measurements for both NGSO and GSO receivers which will give us greater understanding of their resilience to interference. To support this work, we may ask relevant operators to provide receivers to enable us to perform these measurements.

NGSO systems sharing with other NGSO systems

6.26 As noted above, several operators are planning to deploy NGSO systems, each comprising of hundreds or thousands of satellites, raising challenges in managing interference between different NGSO systems, and the risk of services being disrupted. Annex 2 explains this issue in more detail and outlines some of the mechanisms by which different NGSO systems can coordinate and share the same spectrum.

6.27 Cooperation between operators is key to ensuring efficient sharing of spectrum and to avoiding the risk of disruption to users. Obligations to coordinate under the ITU Radio Regulations, where NGSO systems are filed through different administrations, are central to achieving this, although (as we discussed in our NGSO licensing consultation) reaching ITU coordination agreements has been challenging.

6.28 Therefore, our role is not to prescribe how NGSO systems should share with each other, but to create the conditions for operators to reach agreements with each other that support efficient use of spectrum, and to act as a back stop if harmful interference should arise. In doing so, we are mindful of the importance of encouraging operators to build systems which are resilient to interference to the extent possible, and in there being an efficient balance between the level of interference protection given to one system and the flexibility for others to transmit.

6.29 We have already introduced updates to our national licensing regime for NGSO earth stations that support NGSO systems sharing the same spectrum. We plan to further address these challenges through:

a) international engagement to improve the international framework for NGSO systems;

b) developing our approach to handling NGSO-NGSO interference; and

c) considering updates to our national NGSO licensing framework to include additional bands and review pricing.

Improving the international framework for NGSO systems

6.30 We have identified two broad concerns with the current international framework for NGSO systems and how it is applied in practice. Each of these concerns might reduce the extent of NGSO deployment, limit the number of different NGSO systems that UK users (as well as users throughout the rest of the world) could benefit from, and result in a less competitive and innovative sector than might otherwise be possible.

6.31 As noted in section 2, the international regulatory system for satellites allows operators to gain international recognition for their spectrum use and the orbital positions of their

satellites by making satellite filings. It operates on an essentially first-come, first-served basis, as operators need to coordinate with earlier filed systems, as per the relevant provisions of Article 9 of the ITU Radio Regulations. At the same time, coordination is a two-way process in which all operators (including earlier filed ones) need to negotiate in good faith in order to enable the most efficient use of spectrum. This means not making unreasonable demands of other operators.

6.32 Our first concern is that, in spite of the above recognised principles, in practice it is difficult for NGSO systems to complete coordination, and this might negatively impact the ability for additional NGSO systems to be deployed. Some of the reasons for this are:

a) Earlier filed systems can demand very high levels of protection from later filed systems, which maximises the performance of earlier systems but can also put severe and unreasonable constraints onto later filed systems. Such constraints might significantly increase the costs and/or reduce the performance of some NGSO systems compared to a situation with a more balanced interference environment.

b) Full information may not be available at the start of the coordination process, as systems still evolve their commercial model and, in consequence, the way they will be operated. This makes coordination inefficient because:

   i) later filed systems lack the required information to plan their measures to mitigate interference, therefore experiencing delays in their development, or;

   ii) later filed systems may need to coordinate with a system that may not end up being deployed in practice or may be deployed in a very different way.

c) Earlier filed systems might file for constellations comprising very large numbers of satellites that are hard for later filed systems to coordinate with, but these systems may never be deployed with such a large number of satellites.

6.33 In general, earlier filed systems may lack incentives to accommodate competitors with later filings.

6.34 Some of these risks exist also for GSO satellites, but international rules and recommendations have evolved over the years to mitigate them in part; for example, there are ITU recommendations that specify the maximum interference one GSO network should expect from another.

6.35 For non-GSO systems there have also been attempts to mitigate some of these risks. For example, in the past we advocated for a milestone process for the bringing into use of NGSO constellations, and WRC-19 adopted new rules through Resolution 35. This partly mitigates risk (c) above. However, we still believe there is more that can be done to strengthen and clarify the international framework for NGSOs.

6.36 Our second concern is that, because of how difficult it is to complete coordination, and because of the potential delays and costs associated with coordinating with earlier filed systems, NGSO operators may be tempted to partially ignore the ITU process and risk deploying as quickly as possible. This might in practice create constraints on later deploying, but earlier filed, NGSO systems if the later filed system is already providing

services. Whilst this can be beneficial in getting new services to users as quickly as possible, there is a risk that it weakens the effectiveness of the ITU filing system in providing a predictable environment for investment in and development of satellite systems.

6.37 We think the principles of the current ITU framework remain important. However, we consider there are changes that could help mitigate the above risks. These include making the NGSO interference environment as clear and predictable as possible and promoting an efficient balance between the level of interference protection given to one system and the flexibility for others to transmit. Specific changes that we plan to consider include the following.

- Creating guidance on how much interference NGSO systems should be prepared to accept from one another.
- Increasing the certainty around the changes NGSO systems may need to undertake during their lifetime, including by:
  - 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
  - ensuring 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.

Handling of NGSO-NGSO interference

6.38 In parallel with improvements to the regulatory framework for coordination of NGSO systems, we also think it is important to develop new approaches to investigating NGSO-NGSO interference, if this were to arise.

6.39 We plan to continue developing our approach to investigating NGSO-NGSO interference and our understanding of the resilience of NGSO systems to interference. Investigation will rely on clear evidence from operators on the impact of interference (especially if this is impacting the satellite receiver), and we expect to provide more guidance on the type of information that we will need from operators.

6.40 We will also continue to promote the development of a globally harmonised approach to handling NGSO-NGSO interference through ISRMM (International Space Radio Monitoring meeting) and the ITU. A globally harmonised approach would help to reduce the risk of prolonged disputes over interference cases if they were to be escalated to administrations and the ITU.

Updates to our NGSO licensing framework - bands and pricing

6.41 As noted above, we have recently introduced a new licensing regime for NGSO earth stations authorised in the UK. This regime encourages cooperation between operators and enables us to take action to deal with harmful interference if services to UK users are impacted. It also supports our aim to enable as many NGSO systems as possible.

6.42 There are two potential ways in which the current regime might evolve in the future:

- **Extension to additional bands.** Our new licensing regime applies to the frequencies authorised by Satellite (Earth Station Network) licence and the Satellite (Non-Geostationary Earth Station) licence that are set out in our statement. As noted in section 4, we expect to consider access to 14.25 – 14.50 GHz, 37.5 – 42.5 GHz, 47.2 – 50.2 GHz and 50.4 – 51.4 GHz. If as a result of that work, we introduced NGSO access to these bands, then our current thinking is that we would simply extend our NGSO licensing regime (i.e. relevant licences and application process) to those additional bands.
- **Pricing.** At present, the licences used for authorising NGSO systems attract a nominal fee that contributes to Ofcom's costs of administering the licence. They do not attempt to reflect the 'opportunity cost' (i.e. the loss of opportunity) that issuing a licence might have on ability to issue other licences, due to the need to manage interference between different licensees. For example, if operators require a significant separation distance (exclusion area) around their gateway earth stations then this could have an opportunity cost, depending on the scarcity of suitable sites for other users. Although we do not have any immediate plans to consider such pricing, this may be a relevant factor when we next review the pricing of our satellite earth station licences. We separately note below (see paragraph 6.61 below) that there is a misalignment with GSO earth station fees that we would review at the same time.

NGSO systems sharing with GSO satellites

6.43 GSO satellites currently deliver significant benefits, including (but far from limited to) the provision of satellite TV to UK users. 27.1% of homes in the UK have satellite pay TV, while 4.8% of homes have a free to view satellite service. In addition, according to the Radio Regulations, in most bands NGSO systems shall not cause unacceptable interference to, or claim protection from, GSO networks. Annex 2 outlines that interference to GSO satellites can occur from a single NGSO system or from aggregate impact of multiple NGSO satellites, and the existing international rules require that in most bands NGSO systems shall not cause unacceptable interference or claim protection from GSO networks.

6.44 Nonetheless, as discussed above, there is significant growth in new NGSO systems which could benefit users in the UK. Therefore, our aim for NGSO-GSO sharing is the assurance of continued GSO benefits, including through strengthening our ability to investigate and enforce against cases of harmful interference, whilst avoiding inefficient constraints on the growth of NGSO systems. These constraints might arise, for example, through overly conservative modelling, or through GSO systems seeking unreasonably high protection.

6.45 Therefore, in addition to our ongoing responsibility to ensure that UK filed NGSO systems comply with the appropriate international regulations for the protection of GSO satellites, we will:

- consider introducing a new licence condition to deal with NGSO downlinks causing harmful interference to GSO receivers in the UK;

- develop our ability to verify and investigate cases of suspected harmful interference to GSO satellites (where this is brought to our attention), as well as contributing to the development of a recognised international approach to investigating NGSO to GSO interference; and
- engage with international discussions on the evolution of regulations on NGSO-GSO sharing, to promote an appropriate balance between assurance of GSO benefits and efficient sharing with NGSO systems.

Introducing licence terms to put conditions on NGSO downlinks

6.46 We already have conditions in our NGSO licences requiring earth stations to comply with the equivalent power flux-density limitations specified in Article 22 of the ITU Radio Regulations which are intended to protect GSO satellites. This deals with the uplinks from earth stations located in the UK. Harmful interference occurring on the downlink, i.e. from a NGSO satellite transmitting into the UK, could at present be dealt with by contacting the administration responsible for the filing that the satellite is operating under (or for a UK filing, by us taking action under our satellite filing procedures).

6.47 However, we will consider introducing an explicit condition into NGSO earth station licences to require that the satellite downlinking to the earth station also complies with the limits in Article 22. As discussed in section 5 (paragraphs 5.76 – 5.79), this would enable us to enforce directly against the UK licensee if this condition was not complied with.[82] In introducing such a requirement we would need to consider who could ensure compliance, e.g. whether it would be appropriate if the licence were held by an UK service provider, rather than an operator.[83]

Developing our capabilities for handling NGSO to GSO interference

6.48 In addition to introducing new licence terms, we also need to be able to investigate and verify any complaints of NGSO to GSO harmful interference if these were to arise, and regardless of whether they are caused by a single satellite or by the aggregate effect of many satellites (see annex 2 for an overview of the different interference mechanisms). As a consequence, we will develop two separate approaches for interference investigation.

6.49 Our approach to handling NGSO-GSO interference arising from a single NGSO satellite, would be to seek evidence of measurements conducted at victim earth stations (i.e. at the user or operators site). We are aiming to specify a measurement method which operators can follow to provide relevant evidence of interference to Ofcom. For the investigation of aggregate interference, we would use our satellite monitoring facility at Baldock.

[82] This would depend on the NGSO user terminals being authorised under a licence rather than exemption. Although some Ka band terminals are currently exempt, we have separately stated our intention to remove the exemption so these will end up being authorised under network licences.
[83] We considered a similar issue when we recently introduced new conditions into NGSO network licences.

6.50 These techniques are relevant for space to Earth downlinks. For Earth to space uplinks, provision of clear evidence from operators will be critical to enable us to investigate interference.

6.51 In addition to developing our national capabilities we will promote a globally harmonised approach to handling NGSO to GSO interference (similarly as for NGSO-NGSO interference above).

International regulations on NGSO-GSO sharing

6.52 We support improvements to the way NGSO systems are modelled when assessing their interference potential towards GSO systems. The methodology used by the ITU is contained in Recommendation ITU-R S.1503, and our assessment of it shows that some aspects of it result in unnecessary constraints to NGSO systems.

NGSO downlinks sharing with Radio Astronomy

6.53 The downlink (space to Earth) for some NGSO (as well as GSO) systems operate in frequencies which are adjacent to those allocated for radio astronomy use.[84] However, with the deployment of several large NGSO constellations, and due to the fact NGSO satellites are always in motion, the likelihood of space to Earth interference caused by NGSO satellites above radio astronomy sites is considerably higher than GSO satellites. Therefore, as explained further in annex 2, the aggregate interference caused by NGSO satellites visible to radio astronomy sites could, without appropriate mitigation, impact the operations of radio astronomy in the adjacent bands.

6.54 This concern is not completely new, as in the past there were cases of interference to radio astronomy sites caused by an MSS NGSO operator.

New licence conditions to ensure protection of radio astronomy

6.55 We propose to consider updates to NGSO licences[85] to include a requirement that satellite systems must comply with the relevant thresholds[86] to protect the bands allocated to radio astronomy at radio astronomy sites. There may be several ways to comply with these thresholds, NGSO systems may, for example, consider switching off channels immediately adjacent to allocated radio astronomy bands when in the visibility of protected radio astronomy sites.

6.56 We note that some earth stations that operate adjacent to radio astronomy are currently authorised via licence exemption which would hinder the effectiveness of such a condition. However, in line with the approach discussed in section 5, we will consider transitioning

[84] For example, 1.6100-1.6106GHz, 1.613-1.626 GHz and 10.7-10.95 GHz frequency bands are adjacent to bands allocated for radio astronomy use.
[85] Although the interference risks primarily arise for NGSO transmissions, we will consider whether to also introduce for GSO licences for completeness.
[86] A complete list of thresholds is presented in recommendation, ITU-R RA.769-2. Recommendation ITU-R RA.1031 states that many radio astronomy measurements can tolerate interference from a shared service if interference exceeds the thresholds given in ITU-R RA.769 - 2, for no more than 2% of the time.

them to network licences, and this will enable conditions for the protection of other services, including radio astronomy to be introduced.

Handling of NGSO interference to Radio Astronomy

6.57 The introduction of NGSO mega constellations will change the handling of radio astronomy interference investigation. NGSO satellite operators are expected to implement site specific solutions for the protection of radio astronomy sites and, therefore it will be necessary to conduct interference measurements at or close to radio astronomy sites as the impact of any interference is likely to be very localised.

6.58 We will work closely with radio astronomy community on the development of a new approach which will involve interference measurements closer to radio astronomy sites to assess the impact of interference from NGSO satellite systems.

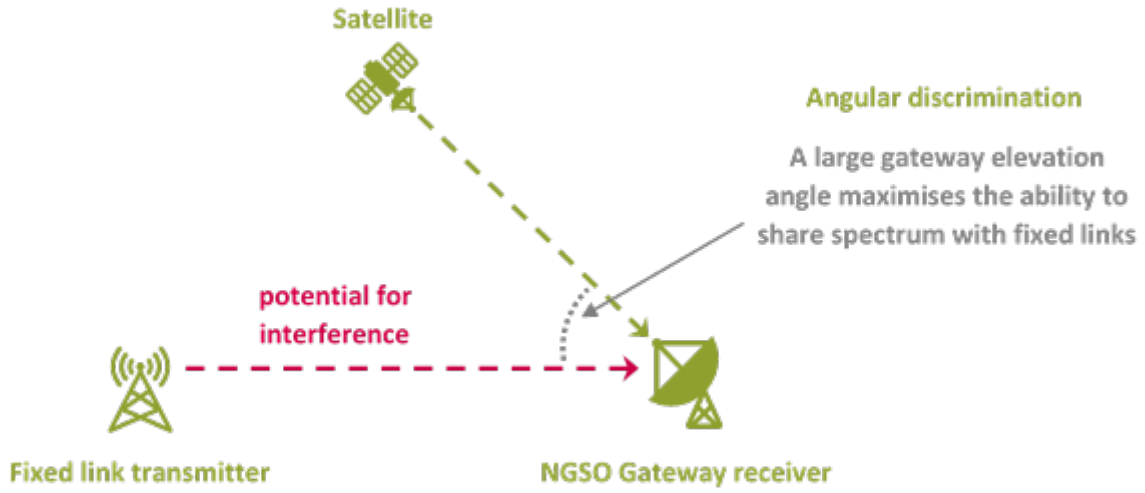
NGSO systems sharing with terrestrial services

Fixed links

6.59 At present we authorise NGSO gateway earth stations (using the NGSO earth station licence) with downlinks in the 17.7 – 19.7 GHz band that is in active use by fixed links. Current indications are that although NGSO gateway earth stations can impact link deployment in a wider range of directions than GSO gateway earth stations, they can have less of an impact with respect to fixed links if they operate at relatively high angles, i.e. comparable to the many existing GSO earth stations operating at higher elevations (see figure below).

6.60 In addition, similar to sharing to GSO gateway earth stations, if the fixed link transmitter is pointing just a few degrees away from the gateway receiver then this can significantly increase the ability to share spectrum.

Figure 4: Ability of NGSO gateway earth station receiver to share with fixed link transmitter



6.61 As noted above (paragraph 6.42), our fees for NGSO licences contribute to Ofcom's costs of administering the licence. Unlike GSO earth stations, they do not currently reflect the 'opportunity cost' (i.e. the loss of opportunity) on our ability to issue fixed links in this shared band. Although we do not have any immediate plans, we expect to revisit this issue when we next review the pricing of satellite earth station licences.

6.62 We are engaging in studies (as part of WRC-23 Agenda Item 1.16) on sharing between NGSO ESIMs on aircraft and ships, and fixed links.

Mobile

6.63 NGSO earth stations do not currently share with terrestrial mobile services in the UK. However, this might change in the future. In section 5, we said we will consider developing our approach to licensing (GSO and NGSO) satellite earth stations in Q/V bands, which partly overlap with bands being considered for 5G terrestrial mobile services. We also noted work looking at satellites sharing with mobile in bands that are currently used by terrestrial mobile services.

Adjacent band users

6.64 There are other terrestrial users who operate in bands which are currently adjacent to bands with GSO earth stations and which may in the future be adjacent to NGSO earth stations. Our general position on users in adjacent bands (as reiterated in our spectrum management strategy statement) is that we will not generally expect to act on interference if it is a result of the poor performance of receivers or wider systems, i.e. if they are impacted by signals outside the band in which they are receiving. One of the ways these users can protect themselves is by ensuring that their receivers are sufficiently selective and filter out any unwanted signals from the neighbouring band.

MSS NGSO communication systems below 1 GHz

6.65 We are seeing increased interest in spectrum access for MSS systems operating below 1GHz (VHF/UHF) where the growth appears to be driven by introduction of low-cost small satellites. Several satellite operators have planned to deploy NGSO constellations to provide IoT/M2M services, and as discussed in section 5, these applications may provide benefits to some users in remote locations in the UK.

6.66 MSS systems generally support low data rates (limited to a few hundred kbits/s) due to a small number of frequencies available for each MSS user or per channel. In addition, MSS mobile stations often have non-directional antennas, which means that their antennas transmit radio waves in all directions, unlike in FSS systems which direct their radio waves in a specified direction towards a satellite. Non-directional antennas can make frequency sharing between MSS systems difficult. To share frequency bands MSS systems may need

to agree on interference mitigation mechanisms[87] that reduce interference or the probability of transmitting at the same time as other MSS systems as well as with terrestrial services.

6.67 Frequency sharing between MSS systems or networks without the use of any interference mitigation techniques could result in interference and possibly data losses. However, as many of the applications being deployed do not require immediate, real-time communication (e.g. because they send periodic measurements), the impact of data losses can be less significant than for the broadband applications support by NGSO FSS systems (discussed above).

6.68 Nonetheless, we have identified actions below – nationally and in CEPT – that we believe will support sharing of spectrum by MSS NGSO systems in the future. We are not seeking additional international allocations for these systems at present.

Updates to national authorisation approach

6.69 MSS systems operating below 1 GHz are currently authorised on a licence exempt basis in the UK. As discussed in section 5, we believe there are potential benefits in moving from exemption to light licensing in the space sector, including the bands used by MSS systems below 1 GHz, given the growing importance of sharing spectrum in these bands . This may provide greater options for managing the sharing environment in these bands in the future. Going forward, we would consider specific cases and consult on any proposed changes as appropriate.

6.70 In addition, we are aware that there are some MSS systems being developed which use bands that are not currently authorised in the UK. When we make proposals on introducing network licences for MSS systems we will consider whether to authorise additional bands, taking account of the likely benefits of doing so.

6.71 At present, the scale of the sharing challenges for these systems appear less likely to justify the licensing process we have introduced for FSS NGSO systems.[88] However, we will keep this under review, for example if we see the risk of negative impact to UK users.

Reform of the CEPT framework for MSS systems below 1 GHz

6.72 The CEPT framework (under ERC Decision (99)06[89]) for MSS systems below 1GHz was developed more than 20 years ago. Given rapid developments in the satellite sector, we think this framework is no longer fit for purpose and risks creating delays and barriers for new entrants.

[87] such as transmission duration or transmit burst duration, duty cycles, use of different polarisations, protocols (eg, listen-before-talk), flexible carrier frequencies, and power levels

[88] https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/satellite-earth/non-geo-fss

[89] ERC Decision (99)06, of 10 March 1999, covers the harmonised introduction of satellite personal communication systems operating in the bands below 1 GHz (S-PCS<1GHz).

6.73 We therefore welcome and support the work CEPT is planning to review the framework. We will continue engaging in this work, aiming to streamline the processes to enable speedy access to the spectrum for new MSS systems.

Summary of actions relating to NGSO satellite communication

6.74 The table below sets out the actions under our proposed strategy which relate to NGSO satellite communication systems. These supplement the actions we have identified in section 5, which relate to satellite communications in general (i.e. for GSO and NGSO systems).

Table 6: Actions relating to NGSO satellite communication systems

Issue	Action
Spectrum access for NGSO systems	
Spectrum access for NGSO earth stations	• 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	• Remain supportive of work on WRC-23 Agenda Item 1.16 studying NGSO ESIM provided that incumbent services remain adequately protected.
Efficient use, sharing and assurance for NGSO systems	
NGSO-NGSO sharing: Improvements to International (ITU) framework	Seek international changes to: • 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: • 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.
NGSO-NGSO sharing: Handling of interference	• 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.
NGSO-NGSO sharing: Evolution of national NGSO licensing regime	• 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.
NGSO-GSO sharing	• 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.
NGSO downlinks sharing with Radio Astronomy	• New licence conditions to ensure protection of radio astronomy. • Develop a new approach to handling of NGSO interference to Radio Astronomy.
NGSO systems sharing with fixed links	• 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.
MSS NGSO communication systems below 1 GHz	
MSS NGSO communication systems below 1 GHz	• 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.

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?

7. Next steps

We will publish our conclusions and take forward our work programme

7.1 This document has set out our views on trends in the space sector and how we will refresh our space strategy to respond to these, taking account of our spectrum management strategy published last year.

7.2 We are seeking input from stakeholders in several areas. A full list of consultation questions can be found in annex 5. We ask stakeholders to please submit their views by 5pm on 24 May 2022. Ofcom's consultation principles can be found in annex 4.

7.3 Once we have received stakeholder responses, we will evaluate them. We will publish a statement setting out our final views on a spectrum strategy for the space sector in Q2 2022/3. At the same time we will start to take forward the programme of work which flows from our strategy.

A1. Legal duties and powers

A1.1 It is difficult to set out an overarching general legal framework which applies across all of our functions for every issue considered in this document. However, this annex notes legal duties and powers which are relevant to our work in the space sector.

Our legal duties and powers

A1.2 The exercise of our functions for the space sector are subject to differing legal requirements under UK law, European law and international law.

A1.3 Ofcom has a principal duty in carrying out its functions to "further the interests of citizens in relation to communications matters and of consumers in relevant markets…"

A1.4 We are also required to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum. We consider that, in general, the optimal use of spectrum is most likely to be secured for society if spectrum is used efficiently, i.e. if it is used to produce the maximum benefits for society. These benefits include both the private and broader social value associated with spectrum use.

A1.5 We authorise the use of the radio spectrum by granting wireless telegraphy licences under the Wireless Telegraphy Act 2006 or by making statutory regulations exempting users of particular equipment from the requirement to hold such a licence.

A1.6 Alongside our principal duty and our duty to secure optimal use of spectrum, we have a wide range of other duties (under the Communications Act 2003 and the Wireless Telegraphy Act 2006[90], as well as the requirements under the European Regulatory Framework Directives) that are relevant to, and have an impact on, our spectrum decisions. These include:

a) Promoting competition;

b) Securing the availability throughout the UK of a wide range of electronic communications services; and

c) Securing the availability, throughout the UK, of TV and radio services of high quality and wide appeal, and duties relating to fulfilling the purposes of public service broadcasting in the UK.

A1.7 When taking decisions on spectrum matters we consider all relevant duties, alongside those directly related to our spectrum functions.

A1.8 Broadly speaking, the different legislation which applies to the different functions is as follows:

d) For our "licensing functions" there are key rules which are set out in EU law, the Wireless Telegraphy Act 2006 and the Communications Act 2003;

[90] See in particular sections 3 and 4 of the Communications Act 2003 and section 3 of the Wireless Telegraphy Act 2006.

e) For our “international negotiation functions”, international law, the Communications Act 2003 and directions from the Secretary of State to Ofcom are relevant; and

f) For our “satellite filing functions” there are relevant rules in the Communications Act, the directions from the Secretary of State and under the body of ITU treaty rules which are principally contained within the ITU Constitution, the ITU Convention and the ITU Radio Regulations.

A2. NGSO systems ability to share spectrum with other spectrum users

A2.1 In this annex we explain:

- how NGSO satellite systems use spectrum;
- how they can share that use with other spectrum users, namely:
  - NGSO systems sharing with other NGSO systems;
  - NGSO system sharing with GSO systems; and
  - NGSO systems sharing with radio astronomy.

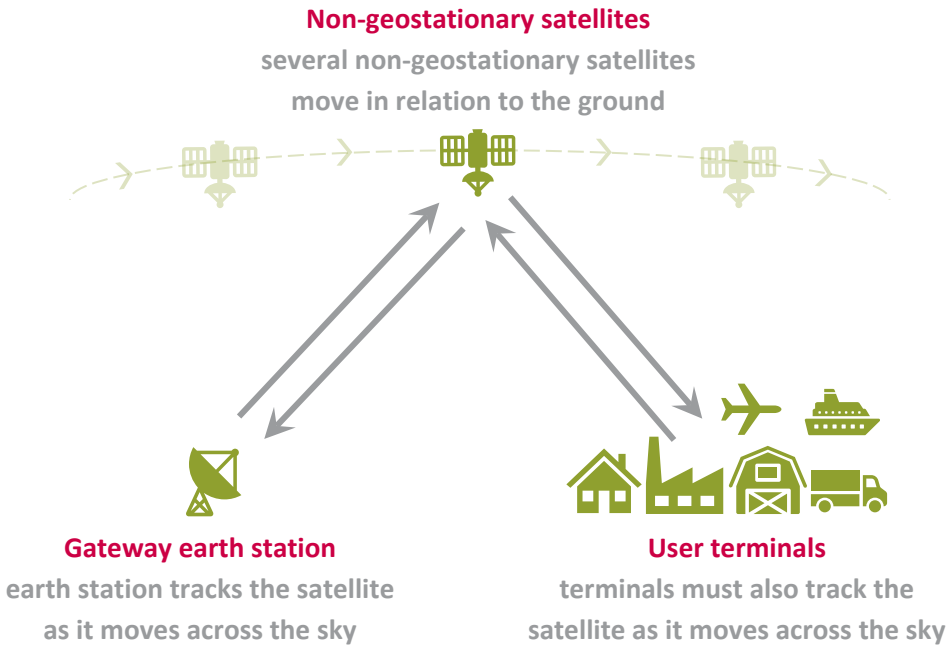
NGSO systems use of spectrum

A2.2 NGSO satellites move around the Earth along predefined "orbital planes". There may be hundreds or thousands of satellites strategically spaced so that, from any point on the surface, at least one satellite is always visible on a direct line of sight. To achieve a continuous connection, gateway earth stations and user terminals are required to track these satellites as they move across the sky, transmitting and receiving information as they do so.

A2.3 In contrast, the satellite dishes used for GSO satellites systems can remain fixed pointing at a single point in the sky.

A2.4 The key elements of an NGSO system are shown in Figure A1 below. **User terminals** typically comprise a small antenna and associated equipment, whilst **gateway earth stations** are typically large hubs that connect the satellite system to the internet and/or to private networks**.**

Figure A1: Key elements of a NGSO satellite system



NGSO systems sharing with other NGSO systems

A2.5 Different NGSO satellite systems can in principle operate using the same spectrum in the same location provided that they have sufficient discrimination in the direction of the interferer. Such discrimination depends on how good their antennas are at concentrating energy to and from one direction, and on the angular separation between the antenna beams of both systems. When beams of two systems point too closely at each other for a short period of time, we say there is an "in-line event". Frequent in-line events could disrupt or degrade services provided to users.

A2.6 This interference can arise on:

- **User links** between the satellite user terminals and the satellite – both in uplink and downlink directions (Figure A2).
- **Gateway links** between the satellite gateway earth stations and the satellite – both in uplink and downlink directions (Figure A3).

Figure A2: Interference between two NGSO systems due to in-line events: User link

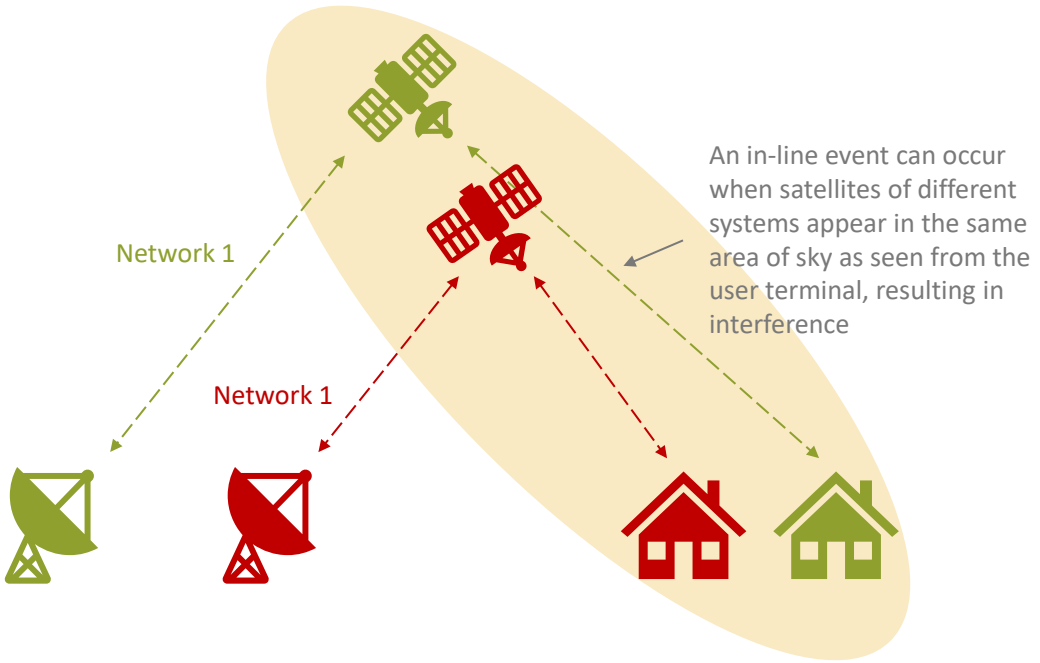
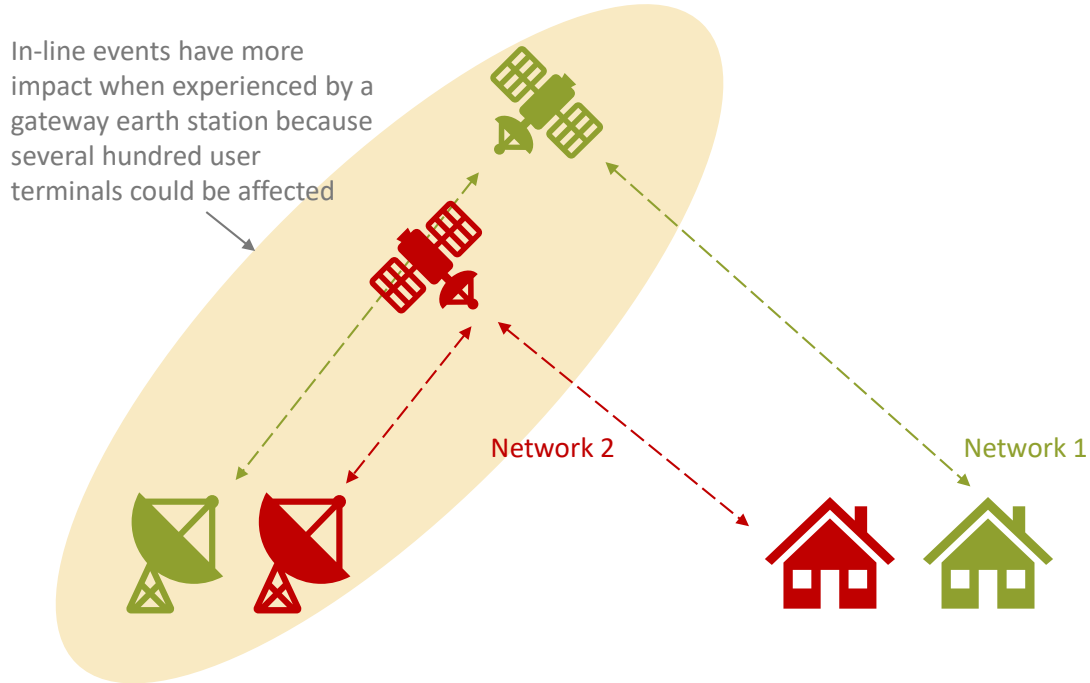


Figure A3: Interference between two NGSO systems due to in-line events: Gateway link



A2.7 Angular separation is the same principle by which different GSO systems can share spectrum, but it is more difficult to achieve between several satellites that are constantly moving. Mechanisms that can support angular separation include:

- **Satellite diversity** – having extra satellites visible from the Earth so that gateways and/or terminals are able to point at different satellites to avoid in-line events.
- **Gateway earth station diversity** – having additional gateways available so that satellites are able to send traffic through different gateway earth stations, avoiding in-line events.
- **Earth station separation** – for example by avoiding placing gateway stations too close to each other.
- **Inter-satellite links** – to allow gateway traffic to be routed via a gateway sufficiently far away from the gateways of another system.

A2.8 Other mechanisms that can facilitate NGSO spectrum sharing include:

- using different **polarization** (the orientation of the oscillations of the radio wave);
- **agreeing to use different frequencies (temporarily) during in-line events** so the signals no longer interfere with each other.

A2.9 Finally, there are mechanisms which do not share access to the same frequencies, but permanently divide up access to it, either by frequency – for example, different operators use different parts of the band – or by geography – different operators serve different countries or geographic regions. These options are much less efficient than options that enable systems to operate in the same frequency and location.

A2.10 The ability of NGSO systems to employ the techniques mentioned above depends on several factors, including their design flexibility and the availability of ephemeris data[91] for each system, which is necessary to understand where the satellites of each system will be and when.

System resilience/impact of interference on services

A2.11 The ability of NGSO systems to share spectrum also depends on the overall resilience of these systems, including the amount of angular separation needed to avoid harmful interference, and to what extent interference during in-line events translates into degraded user services.

A2.12 Since NGSO satellites are moving relative to each other and relative to the ground, in-line events may individually only be brief, maybe a few seconds. However, if an in-line event occurs and causes interference, it may take longer for the terminal to reconnect to the network. The interference could continue to repeat over time, reoccurring in a regular pattern which will depend on the orbits of the respective systems.

A2.13 The exact nature of the disruption to the user will depend on a number of factors, including the design of each satellite system and the robustness of user equipment. The practical impact for users could be on their ability to send and/or receive data, depending on the nature of the interference and the nature of the service being provided. For example:

[91] Ephemeris data refers to information on the exact position of satellites over a period of time.

- If a user is sending data (e.g. uploading a file) it may not get to its final destination as intended or be delayed, due to harmful interference affecting the satellite-to-gateway downlink and/or the user-to-satellite uplink.
- Conversely, if the user is wanting to download data (e.g. watch a video stream) this may be disrupted by interference to the satellite to user downlink and/or gateway to satellite uplink.

A2.14 Because the provision of connectivity to users depends on both the user link and gateway link, interference arising on any of these links can disrupt or degrade a user's internet connection. However, the impact of interference on gateway links would be much greater than on individual user links as each gateway provides connectivity for many users (perhaps hundreds or thousands of users depending on the design of the system), so a loss of connection due to interference at the gateway will be experienced more widely across the network.

A2.15 Factors which affect the resilience of a NGSO satellite systems include:

- **receiver capabilities**, including the ability to quickly adjust modulation and coding schemes and the ability to filter out undesired signals;
- **antenna performance**, as more directive antennas attenuate signals from unwanted directions, and make in-line events shorter; and
- **system design**, including the availability of more than one station to transmit to and/or from (station diversity).

A2.16 We are currently undertaking our own technical studies and measurements to better understand the practical impact of interference between NGSO systems and the resilience of the NGSO systems currently being deployed.

Future developments

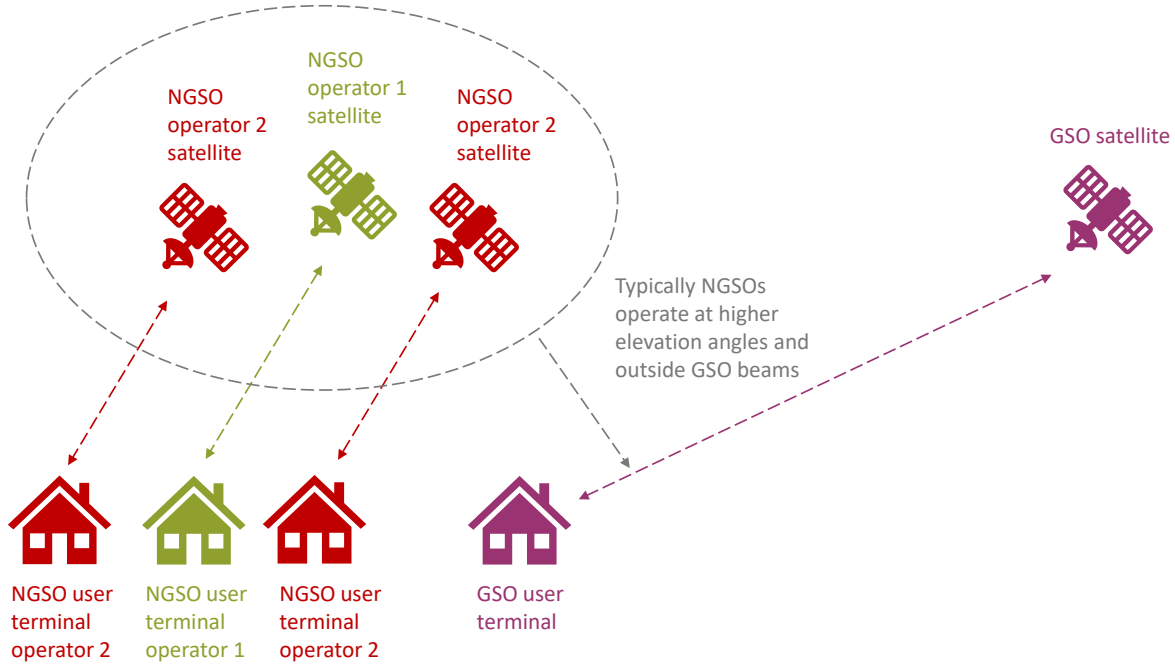
A2.17 In section 6, we noted a number of ways that NGSO systems could develop, creating new challenges and opportunities for sharing spectrum. Given this, we think the future ability of NGSO systems to share spectrum could evolve as follows:

- In order to share spectrum effectively, satellite operators will need to exchange accurate and up-to-date operational information, including the ephemeris data (i.e. the position of satellites over a period of time) mentioned above. We therefore expect to see more initiatives dedicated at facilitating the exchange of such data.
- The widespread introduction of narrow steerable beams to facilitate sharing among NGSO systems, as it will make it easier to avoid in-line events
- The overall effect of increased numbers of satellites per constellation remains unclear. While on the one hand this will increase the average level of interference in a band (as there will be more satellites operating co-frequency), on the other hand this should mean there will be more satellite diversity, allowing operators to avoid in-line events.

NGSO system sharing with GSO systems

A2.18 NGSO systems use the same frequencies that are used by GSO systems and ensure protection[92] of GSO by creating sufficient angular separation between NGSO and GSO beams (see figure A4).

Figure A4: NGSO satellites sharing spectrum with GSO satellite

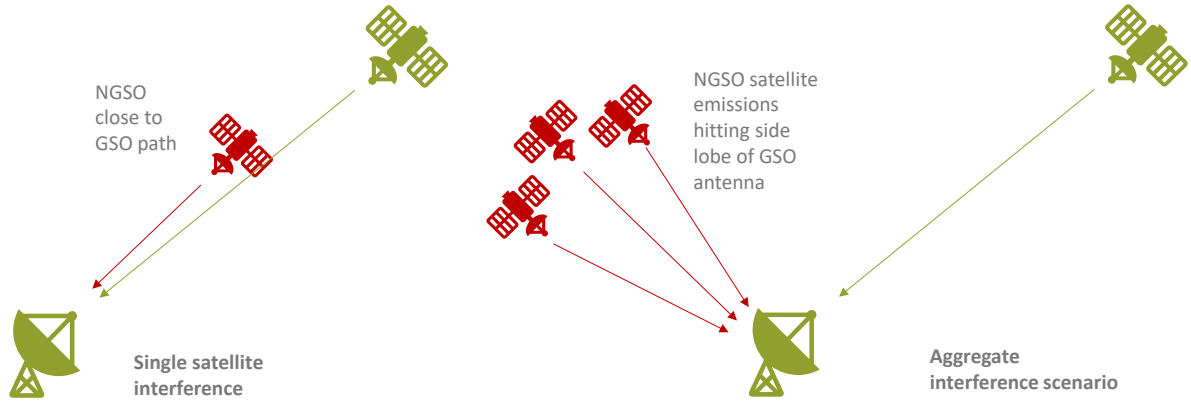


A2.19 In addition, aggregate interference can arise where interference from multiple NGSO satellites arrives through the side lobe[93] of a GSO antenna. If the number of NGSO constellations increases significantly, then the aggregate interference caused to GSO satellites will increase as well. This does not mean that harmful interference will be caused to GSO satellites, but it does mean that administrations and NGSO operators will have to put measures in place to keep aggregate emissions under control. The two key NGSO-GSO interference mechanisms – single satellite and aggregate interference – are shown below.

[92] The control of interference to GSO from NGSO is regulated under Article 22 of the Radio Regulations

[93] The reception pattern of an antenna has a primary beam where the dish is most sensitive (has the maximum gain). However, the antenna also has smaller beams or 'side lobes' that are unwanted and come from directions outside the primary beam.

Figure A5: Two key NGSO-GSO interference mechanisms

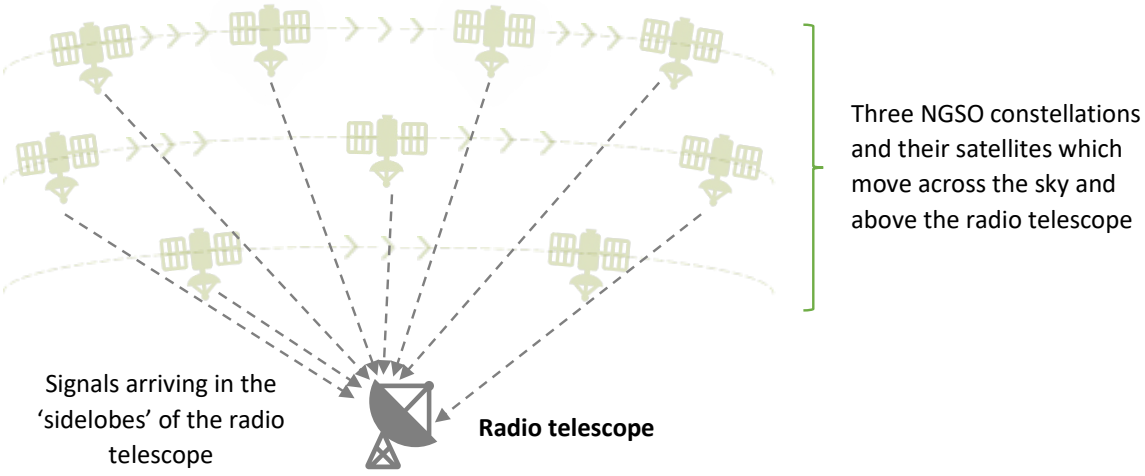


A2.20 As above, we are currently undertaking our own technical studies and measurements to better understand the resilience of GSO receivers to interference from NGSO systems.

NGSO downlinks sharing with Radio Astronomy

A2.21 Aggregate downlink interference from NGSO constellations operating in the adjacent bands to radio astronomy could impact its operations or measurements. Generally, aggregate interference can arise when emissions from multiple NGSO satellites hit the side lobes of a radio telescope (see figure A6 below), in a similar way to the NGSO to GSO case discussed above.

Figure A6: **Aggregate interference caused by several NGSO constellations at the Radio telescope**



A2.22 If the number of NGSO constellations increase significantly, then the aggregate interference caused to radio astronomy could increase as well. Therefore, NGSO operators will have to put measures in place to keep aggregate emissions under control and comply with the thresholds given in the ITU recommendations. Radio astronomers can however reduce susceptibility to interference by performing their observations using the multi-element radio linked interferometer network (e-MERLIN), which is the network of six antennae that provides extra resilience.

A3. Responding to this consultation

How to respond

A3.1 Ofcom would like to receive views and comments on the issues raised in this document, by 5pm on 24 May.

A3.2 You can download a response form from the Ofcom website. You can return this by email or post to the address provided in the response form.

A3.3 If your response is a large file, or has supporting charts, tables or other data, please email it to spacespectrumstrategy2022@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet. This email address is for this consultation only, and will not be valid after 24 May 2022.

A3.4 Responses may alternatively be posted to the address below, marked with the title of the consultation:

Justin Moore
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A3.5 We welcome responses in formats other than print, for example an audio recording or a British Sign Language video. To respond in BSL:

- send us a recording of you signing your response. This should be no longer than 5 minutes. Suitable file formats are DVDs, wmv or QuickTime files; or
- upload a video of you signing your response directly to YouTube (or another hosting site) and send us the link.

A3.6 We will publish a transcript of any audio or video responses we receive (unless your response is confidential)

A3.7 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt of a response submitted to us by email.

A3.8 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.

A3.9 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at annex 6. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

A3.10 If you want to discuss the issues and questions raised in this consultation, please contact Justin Moore by email to justin.moore@ofcom.org.uk.

Confidentiality

A3.11 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish responses on the Ofcom website at regular intervals during and after the consultation period.

A3.12 If you think your response should be kept confidential, please specify which part(s) this applies to, and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.

A3.13 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A3.14 To fulfil our pre-disclosure duty, we may share a copy of your response with the relevant government department before we publish it on our website. This is BEIS for postal matters, and DCMS for all other matters.

A3.15 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further in our Terms of Use.

Next steps

A3.16 Following this consultation period, Ofcom plans to publish a statement in Q2 2022/3.

A3.17 If you wish, you can register to receive mail updates alerting you to new Ofcom publications.

Ofcom's consultation processes

A3.18 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in annex 4.

A3.19 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

A3.20 If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact the corporation secretary:

Corporation Secretary
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA
Email: corporationsecretary@ofcom.org.uk

A4. Ofcom's consultation principles

Ofcom has seven principles that it follows for every public written consultation:

Before the consultation

A4.1 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. If we do not have enough time to do this, we will hold an open meeting to explain our proposals, shortly after announcing the consultation.

During the consultation

A4.2 We will be clear about whom we are consulting, why, on what questions and for how long.

A4.3 We will make the consultation document as short and simple as possible, with an overview of no more than two pages. We will try to make it as easy as possible for people to give us a written response.

A4.4 We will consult for up to ten weeks, depending on the potential impact of our proposals.

A4.5 A person within Ofcom will be in charge of making sure we follow our own guidelines and aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.

A4.6 If we are not able to follow any of these seven principles, we will explain why.

After the consultation

A4.7 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish the responses on our website at regular intervals during and after the consultation period. After the consultation we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

A5. Consultation coversheet

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing ☐

Name/contact details/job title ☐

Whole response ☐

Organisation ☐

Part of the response ☐

If there is no separate annex, which parts? _____

_____

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom aims to publish responses at regular intervals during and after the consultation period. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here.

Name Signed (if hard copy)

A6. Consultation questions

The context for a strategic refresh

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?

Our strategic objectives and priorities

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

Work areas and actions

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?

NGSO satellite communications

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?

A7. Glossary

3GPP	The 3rd 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.
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.
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.
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.