Strategic review of satellite and space science use of spectrum

Call for Input

Publication date: 4 June 2015

Closing Date for Responses: 13 August 2015

About this document

This Call for Input asks for stakeholders' input to Ofcom's strategic review of spectrum used by the satellite and space science sectors. We are keen to understand potential demand and supply trends, as well as trends in technology that might mitigate additional demand. The information provided by stakeholders will help us refine our understanding of the future spectrum challenges facing these two sectors. This understanding will inform the prioritisation of our work in these sectors and our future spectrum policy decisions.

Contents

Section 1

Introduction

1.1 This Call for Input (CFI) asks for stakeholders' input to Ofcom's strategic review of spectrum used by the satellite and space science sectors. This section introduces the aims and rationale for the review, and notes its links to other work that Ofcom is undertaking.

Purpose of the strategic review

1.2 In our 2015/16 Annual Plan[1] we outlined our intention to carry out a strategic review of the satellite and space science sectors. This Call for Input (CFI) is the initial step in that review. Its purpose is to help improve our understanding of stakeholders' views of current and future trends that might impact the demand for, or supply of, spectrum available for use by these sectors.

1.3 The aim of the review is to build on the sectoral analysis and roadmap we published in 2013 as part of our Spectrum Management Strategy (SMS)[2] to refine our understanding of:

- typical applications delivered by the satellite and space science sectors and the benefits these provide to consumers and citizens within the UK, the rest of Europe and more widely where appropriate;
- the value chains for the services and applications delivered by these sectors, the key types of players and their role;
- the high level market and technology trends that could shape the sectors going forward;
- trends in demand for specific applications, considered across the value chain, including the underlying drivers of demand;
- potential mitigation techniques that could help bridge any potential gap between future demand and supply for spectrum.

1.4 The improved understanding we gain from the review will inform our future priorities and policy decisions.

1.5 The review aims to look forward over the medium and long term, up to around 20 years out. This timeframe reflects the long planning times and lifecycles for satellite and space science investments, and the long lead-time for any potential regulatory changes that require international agreement. The review is not aiming to replicate the engagement we already have in place with stakeholders on a range of existing, shorter term issues, including those discussed in the run up to the World Radio Conference 2015 (WRC-15).

[1] http://www.ofcom.org.uk/about/annual-reports-and-plans/annual-plans/annual-plan-2015-16/
[2] See our Consultation, Statement and Appendix of Future development in major spectrum uses at http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/.We also intend to make use of relevant responses to the SMS for this review, as some of those responses raised developments in the satellite and space science sectors in greater detail than was needed for the SMS.

1.6 For the purposes of this review we consider:

- The satellite sector[3] to encompass all commercial and military use of satellite services.
- The space science sector to include all science uses of satellite, space communications and reception of naturally occurring radio emissions. This does not include terrestrial science use of spectrum.

Why we are carrying out a review of these sectors

1.7 Within the context of increasing and competing demand for spectrum from different sectors, it is important for us to have an up-to-date understanding of the trends and drivers influencing the demand for spectrum.

1.8 Following the publication of our SMS in 2013 we have progressed more detailed reviews of a number of sectors and/or bands. For example, we have developed a Mobile Data Strategy[4] and initiated strategic reviews of PMSE spectrum use[5] and UHF bands 1 and 2 (420-470 MHz)[6]. In addition, we are working with the public sector, where relevant, to understand its demand and potential to add to the supply of spectrum for commercial use.

1.9 This review therefore complements the work we are doing in other sectors, particularly on future mobile data services where there has been an increased focus on bands which are of interest to the satellite and space science sectors (for example 3.6-4.2 GHz, 5.3 GHz and bands above 6 GHz[7]).

Other relevant work

1.10 This project is related to a number of other pieces of work including:

- **Mobile Data Strategy**. This project has identified potential bands for future mobile data use below 6 GHz, and is currently identifying bands above 6 GHz for potential future use by 5G mobile technologies;
- **Further opportunities for spectrum sharing**. We plan to consult this year on how to further increase opportunities for spectrum sharing, as previously indicated in our SMS. Subject to the consultation process, this may lead to opportunities for more, and more effective, sharing across a range of spectrum bands and applications;
- **Implementation of the Radio Equipment Directive.** This work in Europe includes the introduction of receiver performance into the standardisation process for new and existing standards, and hence may facilitate greater spectrum sharing between different users in the future; and

[3] Whilst this CFI does not explicitly address amateur use of satellites, we are interested in views of the amateur satellite community where relevant.
[4] See http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/
[5] For example, see http://stakeholders.ofcom.org.uk/consultations/pssr-2014/statement
[6] See http://stakeholders.ofcom.org.uk/consultations/420-470-mhz/
[7] See http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/ and http://stakeholders.ofcom.org.uk/consultations/above-6ghz/

- **Spectrum Information**. As stated in our SMS, we are seeking to make more and better information available to stakeholders on spectrum use. We are also keen to gather and analyse information from various sources to build a more comprehensive picture of the sectors for which we authorise spectrum use.

Document structure

1.11 The remainder of this document is structured as follows:

- **Section 2** sets out our approach to the review;
- **Section 3** defines the types of services and applications that are in scope of the review;
- **Section 4** sets out the key areas where we are seeking information from stakeholders in the satellite sector;
- **Section 5** sets out the key areas where we are seeking information from stakeholders in the space science sector; and
- **Section 6** outlines our next steps for the review.

Section 2

Our approach

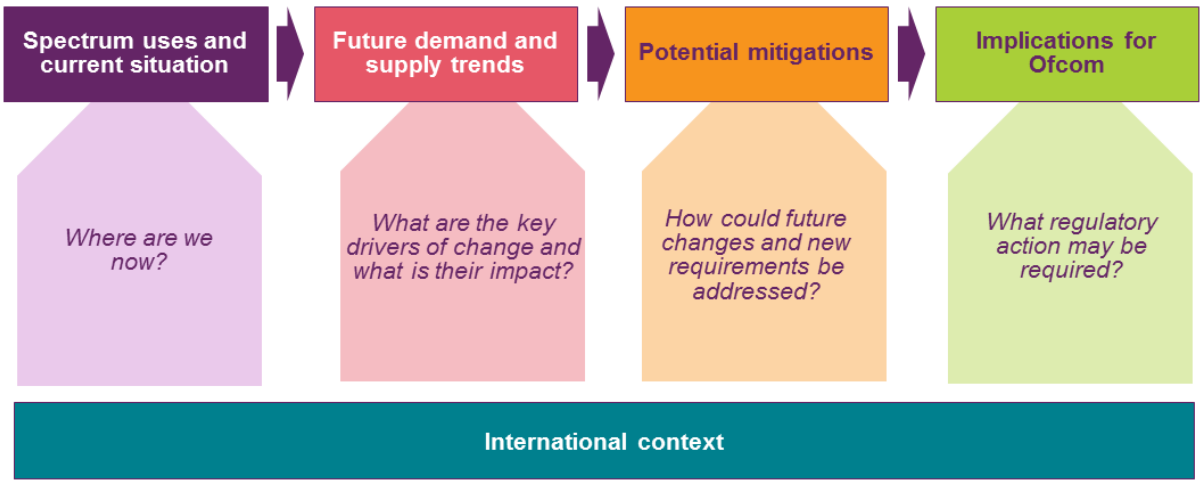
2.1 Our proposed approach to the review is to:

- understand current use, by application and geography, of bands available for use by the two sectors;
- consider trends in different parts of the value chain, for example the impact of new technologies and business models, that could affect spectrum demand and supply over the next 10 to 20 years;
- consider the mitigating actions (e.g. use of improved technology) that could address changing spectrum requirements; and
- review whether developments in demand, supply and mitigation, mean that regulatory action by Ofcom (in conjunction with regulators in other countries) is likely to be needed to address any imbalance(s).

2.2 We will also take account of the important international context for each of these elements.

2.3 This is a similar framework to that used in our overall SMS but takes the analysis to a greater level of detail. Figure 1 below illustrates the analytical framework and the rest of this section sets out how we will apply this framework to this review.

Figure 1: Analytical framework for the strategic review



International context

2.4 The international context of the review is particularly important because:

- Satellite and space science applications are typically provided on an international basis. For example, a single geostationary (GSO) satellite may provide services to nearly one third of the Earth. Space science satellites may gather measurements across the whole of the Earth in order to inform research on global climate changes.

- Spectrum use by these sectors is significantly influenced by international processes and decisions, including the processing of satellite filings by the ITU and spectrum allocation decisions at WRCs.

2.5 As a result, our analysis will not only consider the interests of UK citizens and consumers, but also take account of the international nature of the satellite and space science sectors. We will, for example, consider how international developments could influence demand, supply and the available options for mitigating imbalances between demand and supply.

2.6 In addition, any regulatory implications of the review are quite likely to involve actions at an international level. However, as noted above, the focus of this review is on longer term strategy and not on the issues being considered at WRC-15.

Spectrum uses and current situation

2.7 It is important for us to have a solid understanding of how the satellite and space science sectors currently operate as a starting point for this review. For each sector, we want to improve our understanding of:

- the value chain and its various components;
- how bands are currently used in the UK, the nature of the benefits to UK citizens and consumers generated by the sector (including the balance between private and wider social benefits) and the main applications that deliver these benefits; and
- the use of satellite and space science applications outside the UK, particularly in Europe, but also more widely where this has implications for UK use of spectrum and/or vice-versa.

Future demand and supply trends

2.8 We aim to develop a more detailed view of demand for each application by understanding the demand drivers and trends across the various components of the value chain. For example, changing spectrum demand could be driven by an increasing demand for consumer satellite broadband, the desire for greater resolution in space science imaging data, or by increasing demand from the public sector.

2.9 We will examine demand alongside any potential changes in supply. For example, changes to the ITU Radio Regulations to allow Earth Stations on Mobile Platforms (ESOMPs) to use FSS frequency bands could increase the spectrum available for satellite applications that use ESOMPs.

Potential mitigations

2.10 The review will also consider any mitigating actions that may be taken by users, industry and/or regulators to address changing spectrum requirements. Potential mitigations may include improved technologies and standards, such as better modulation and coding techniques; better re-use of the spectrum that is currently available; as well as making new bands available to these sectors.

Implications for Ofcom

2.11 The review will inform what, if any, regulatory action(s) we should consider taking, at a national and/or international level, for example seeking additional international allocations or facilitating greater spectrum sharing.

Question 1: Do you have any comments on our approach to this review?

Section 3

Scope of the review

3.1 This section defines the scope of this review by reference to both:

- the ITU radiocommunication services that are relevant to the sector. These are significant because the ITU Radio Regulations allocate spectrum to the satellite and space science sectors using these service definitions; and
- the main applications that the sectors provide, with a separate table showing which ITU service(s) are typically used to provide each of these applications.

Satellite sector

Relevant ITU services

3.2 In the majority of cases, space sector applications make use of spectrum allocated to one (or more) of the following services, as defined in the ITU's Radio Regulations and summarised in simplified terms below:

- *Fixed Satellite Service (FSS)*: two-way communication links between satellites and earth stations. These are typically at a fixed point on the Earth when operating, but now also include ESOMPs. This service typically makes use of portions of the C-, Ku- and Ka-bands;
- *Mobile Satellite Service (MSS)*: two-way communication links between portable user terminals and satellites The MSS is particularly well suited to providing services to areas usually not reached economically by other communication means, such as oceans and polar regions. It typically makes use of portions of the L- and S-bands. Parts of these bands are typically assigned to individual satellite operators on an exclusive use basis because co-coverage and co-frequency sharing of MSS spectrum is usually difficult to achieve as user terminals are usually equipped with omni-directional antennae. Specific types of MSS include:
  - *Aeronautical Mobile Satellite Service (AMSS)*: a particular type of MSS for which the earth stations are located on board aircraft;
  - *Aeronautical Mobile Satellite (Route) Service (AMS(R)S)*: a particular type of AMSS reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes;
  - *Maritime Mobile Satellite Service (MMSS)*: a particular type of MSS for which the user terminals are located on board ships; the Global Maritime Distress and Safety System (GMDSS) also operates under this service;
- Broadcasting *Satellite Service (BSS)*: one-way transmission of high-power broadcast signals from a satellite directly to consumers, who receive the signals using relatively small and affordable satellite dishes. The service typically uses portions of the C- and Ku-bands;

- *Radionavigation Satellite Service (RNSS):* one-way transmission of signals from constellations of satellites towards the Earth. The coded and time-stamped signals are used to determine the position and velocity of receive-only terminals on the Earth and to synchronise a range of devices to a single time reference. These systems typically make use of portions of L-band spectrum;

- *Space Operations Service (Space Operations):* communication concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand; and

- *Inter Satellite Service (ISS)*: two-way transmission of signals between two or more satellites. Typically these are used for non-geostationary constellations of satellites to relay transmissions between individual satellites.

Applications of the satellite sector

3.3 The main applications which make use of spectrum allocated to the services identified above are listed below. We cluster the applications into two groups: those that are offered directly to the end-users and those which support other applications.

<u>End-user applications</u>

- *Direct-to-Home (DTH) Broadcast TV*: broadcasting of television content (both free-to-air and subscription based) directly to consumers who receive it with a satellite dish and receiver at home;

- *Broadband internet access*: provision of Internet access services that make use of satellite capacity for residential and business users. This service is typically used in locations where terrestrial broadband access services like xDSL, cable or fibre either do not exist or only offer a low quality service;

- *Machine-to-Machine (M2M)*: communication via a satellite link between devices rather than between users;

- *Commercial Mobility*: all mobility services to commercial and individual (i.e. non-governmental/military) users. Typical applications include maritime communications for both vessels and offshore platforms (e.g. oil rigs), aeronautical and land mobile applications (e.g. satellite phones);

- *Corporate Networks*: this includes the provision to corporate users of two-way data services, for example using very small aperture terminal (VSAT) networks, usually offered subject to specific Quality of Service (QoS) contractual agreements;

- *Disaster Relief*: all applications that are used to provide communication services for the specific purpose of humanitarian aid and support after a disaster (e.g. earthquakes, tsunamis, etc.);

- *Emergency distress alert:* detection and location of emergency beacons activated (manually or automatically) by people in distress. The most well-known example is the International Cospas-Sarsat Programme, used for identifying alerts sent by aircraft, ships and backcountry hikers in danger; and

- *Navigation (including location based):* the provision of satellite capacity used to determine the position of a vehicle or a person on the Earth. Examples of Global

Navigation Satellite Systems (GNSS) include the US Global Positioning System (GPS) and the future, EU-backed Galileo system.

Other applications

- *Distribution of broadcast content:* transport of television, radio and interactive channels for their subsequent delivery through television broadcast, cable and IPTV networks to the end-user. Typical users of this application are companies offering cable head-ends, free-to-air services, channel bouquets, and distribution of television network channels to local affiliates and/or to terrestrial television broadcast towers for over-the-air distribution;

- *Contribution and Occasional Use (OU) TV:* this includes the use of satellite capacity by media companies, major TV networks, news organisations, pay TV service operators, and others to move video and other content from one location to another prior to distribution – not necessarily via satellite – to television viewers. One example is satellite news gathering earth stations that use satellite capacity to transmit live events to the studio of a TV channel; and

- *Legacy telephony and carrier:* this includes point-to-point communication links purchased by commercial fixed line network companies to offer services such as private lines that can transport voice, data and video. This application may also include the leasing of capacity to be used as a backup for other links (e.g. terrestrial microwave, fibre, etc.) and/or to accommodate short periods of high demand at particular locations.

3.4 Military and government users make use of a range of end-user and other applications, such as the deployment of Unmanned Aerial Vehicles (UAVs), the provision of communication services to vessels, land vehicles and aircraft (communications on the move (COTM) or, for static personnel, communications on the pause (COTP)). These users may lease capacity in bands used by commercial applications as well as using so-called “military bands” (UK2).

3.5 Table 1 below sets out a summary of these applications and the associated ITU radiocommunications services.

Question 2: Do you have any comments on our broad overview of the satellite sector set out in this section? In particular, do you have comments on the completeness of the list of applications, their definitions and their use of the relevant ITU radiocommunications service(s)?

Table 1: Applications and corresponding services of the satellite sector

Application	ITU radiocommunications service(s)
End-user applications	
Direct-to-Home Broadcast TV	FSS, BSS
Broadband internet access	FSS
Machine-to-Machine (M2M)	MSS (including ISS)
Commercial Mobility	MSS (including ISS), FSS[8], MMSS, AMSS
Corporate Networks	FSS (including ISS)
Emergency distress alert	MMSS (limited to the operation of the GMDSS), AMS(R)S
Navigation including location based	RNSS
Other applications	
Distribution	FSS, BSS
Contribution and OU TV	FSS, BSS
Legacy telephony and carrier	FSS
Telemetry, tracking and command	Space Operations, FSS
Military and government	FSS, MSS, ISS, MMSS (including the operation of the GMDSS), AMSS, AMS(R)S, RNSS

3.6 In addition to their use of spectrum for the service links to users (e.g. the communications link between a satellite and an MSS user terminal), these applications will also use spectrum for the feeder / backhaul links between the satellite and its earth gateway station(s) and for telemetry, tracking and command (TT&C)[9] - with different frequencies used for both earth to space and space to earth directions where relevant.

3.7 The distinction between service links, feeder links and TT&C links is potentially significant for spectrum allocation and management since they have different implications as regards their ability to share spectrum access (and the questions in section 4 reflect this).

[8] The use of FSS for mobile applications is subject to various regulatory provisions (e.g. ITU-R Resolution 902 (WRC-03) or footnote No. 5.526 of the ITU RR)

[9] These links operate and control a satellite. For example, such links are used to receive monitoring data from the satellite on its health and functioning (telemetry); track the location of the satellite (tracking); send commands from the ground to the satellite to satisfy operational mission requirements or to respond to emergency conditions (command)

Space science sector

Relevant ITU services

3.8 Space science applications make use of spectrum allocated to one (or more) of the following services, as defined in the ITU's Radio Regulations, and summarised in simplified terms below:

- *Earth Exploration Satellite Service (EESS)*: the use of satellites with active or passive sensors to study the Earth, including the its physical characteristics (e.g. sea levels and temperature, the ozone layer), climate change, natural hazards, agriculture (e.g. droughts, crop distribution), security monitoring and disaster prediction;

- *Space Research Service (SRS):* the use of spectrum to study the physical characteristics of other celestial bodies including planets using equipment mounted on satellites.

- *Radio Astronomy Service (RAS)*: the ground based reception of naturally occurring emissions in order to research astrophysics and cosmology. Typically 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; and

- *Space exploration and space operations*: the use of spectrum where communications are needed between space facilities on Earth and spacecraft in outer space or on other celestial bodies as well as space-to-space communications.

Applications of the space science sector

3.9 Space science use of spectrum can most usefully be categorised into two groups:

- those which are passive – for the reception and measurement of naturally occurring radio emissions. These typically monitor specific aspects of the Earth's surface and atmosphere, as well as extra-terrestrial radiation; and

- those which are active – for the transmission of radio signals to take measurements (e.g. by radar).

3.10 Data collected through active and passive sensing are subsequently combined and processed and are used for a wide range of end user applications, such as:

- Weather forecasting (general public, military, aviation/maritime/highway agencies etc.);

- Security & agriculture monitoring;

- Disaster prediction & management;

- Space weather forecasting; and

- Climate change research.

Passive applications

- *Radio astronomy:* use of earth stations on the ground to monitor naturally occurring radio emissions from celestial bodies and outer space, and the Doppler Effect (caused by the relative movement of the celestial bodies to the Earth and the expansion of the Universe), to aid research into astrophysics and astronomy;

- *Passive earth sensing:* use of receive-only sensors on satellites to monitor naturally occurring radio emissions created by the physical characteristics of Earth. This includes monitoring of soil moisture and ocean salinity, sea surface temperature, surface rainfall rate, and surface wind speed; and

- *Passive space sensing.* use of receive-only sensors to monitor naturally occurring radio emissions created by the physical characteristics of other celestial bodies and space objects. This is a radio astronomy application, but with the sensors based in space rather than on the ground.

Active applications

- *Active earth sensing:* covers a wide range of applications that collect data on Earth's physical characteristics. Examples include scatterometers providing near surface wind speed and altimeters providing terrain height, sea level, wave height, wind speed, as well as use by synthetic aperture[10] and precipitation radars;

- *Active space sensing:* similar to earth sensing but radars are used for mapping planets, comets and other space objects. For example, space borne radars are used in the mapping of other planets such as Mars. As this use of spectrum is for deep space missions it does not constrain terrestrial spectrum use;

- *Space exploration data communications (deep space missions):* used for communications with space exploration spacecraft, for example communications with deep space missions to Mars and other planets. This includes space-to-Earth (s-E), Earth-to-space (E-s) and space-to-space (s-s) communications. There are very few earth stations used for this application. As they are highly sensitive to interference they are typically located in remote locations; and

- *Space science data communications (near earth missions):* used to retrieve space science data collected by spacecraft and space science satellites. For example receive-only earth stations (ROES) are used to collect data from meteorological and earth exploration satellites. This application also includes communications from the International Space Station.

3.11 Table 2 below summarises the applications and the corresponding ITU radiocommunications services by which the application are typically delivered.

[10] Synthetic aperture radar (SAR) is a space borne radar used for imagining applications

Table 2: Applications and corresponding services of the space science sector

Application	**ITU radiocommunications service**
Passive applications	
Ground based Radio astronomy	RAS
Passive earth sensing	EESS (passive)
Passive space sensing /Space-based radio astronomy	SRS (passive)
Measurements and dissemination of information related to the weather and environment.	MetSat
Active applications	
Active earth sensing	EESS (active), Radiolocation
Active space sensing	SRS (active)
Telecommand, Telemetry and Control	Space Operations
Space exploration communications	SRS (deep space)
Space Science data communications	EESS, SRS

3.12 As in the case of satellite services, there is an important distinction between the spectrum used by the space science application itself (e.g. passive sensing), the spectrum used by a satellite to downlink the data (collected by the application) back to earth station(s) and the spectrum used for TT&C. The questions in section 5 reflect this.

Question 3: Do you have any comments on our broad overview of the space science sector? In particular, do you have comments on the completeness of the list of applications, their definitions and their use of the relevant radiocommunications service(s)?

Section 4

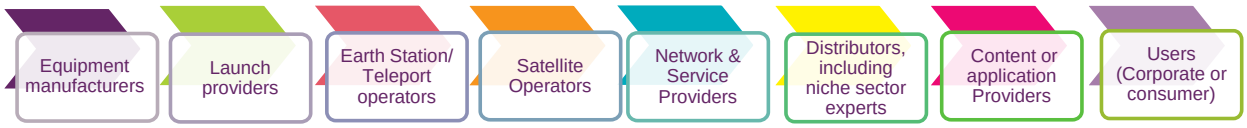
Refining our understanding of the satellite sector

4.1 This section discusses a number of areas where additional information about the satellite sector would help inform our review. The section invites stakeholders to answer questions about the sector's value chain, current spectrum use, future demand and supply trends, potential mitigations for changing spectrum requirements and the potential implications for Ofcom.

Value chain for the satellite sector

4.2 The value chain for the satellite sector includes a wide variety of players who deliver the applications summarised in Table 1. To help clarify the roles of different players, Figure 2 below provides a 'generic' value chain which we believe reflects the key aspects of the satellite sector

Figure 2: Satellite sector value chain



4.3 The various components of the value chain can be described as follows:

- *Equipment manufacturers:* manufacturers of all equipment used in the delivery of satellite services – from satellites, launchers, earth stations, to user terminals, such as DTH dishes and set top boxes;
- *Launch providers:* companies that offer launch facilities for both GSO and non-GSO satellites;
- *Earth station/Teleport operators:* companies that manage and operate earth stations and teleports for themselves or on behalf of others. A teleport is a physical site usually owned by a single company where a relatively large number of earth stations are co-located. Earth stations can be owned by a variety of organisations, provide services to a range of customers, and take a range of forms, including, for example, transportable earth stations used to provide satellite newsgathering services;
- *Satellite operators:* companies that procure and operate satellites to offer transponder capacity;
- *Network and service providers:* companies that develop networks and services using capacity leased from satellite operators for themselves or to sell to others;
- *Distributors:* companies that sell services and networks to end users, corporate or residential;
- *Content or application providers:* companies that produce content or applications that are delivered over satellite; and,

- *Users:* users of the applications delivered over satellite.

Question 4: Do you have any comments on our representation of the value chain for the satellite sector? How do you think industry revenues are broken down between players at different positions in the chain?

4.4 As with any value chain, we understand that individual companies may play more than one role in the value chain. For example many satellite operators also act as network or service providers and may also distribute their services to end users.

4.5 An individual company may be a *user* of satellite applications and/or *provide* them to customers. For example, a broadcaster may use content distribution services and be a provider of DTH broadcast TV. In addition, companies may help to deliver downstream applications, even if they do not provide them themselves. For example, a satellite operator may help to deliver DTH broadcast TV by providing satellite capacity to a DTH TV provider, even if it does not directly offer this application to the end user.

4.6 We are seeking stakeholders' input and views to better understand the roles of the players in each component of the value chain. This will help us to contextualise the responses we receive from individual stakeholders given their specific role(s) in the value chain.

4.7 We also appreciate that different players in the value chain will have a different perspective on the satellite industry and that some players may have little or no visibility of the individual applications that are delivered (e.g. launch providers may have limited knowledge of the type of satellite applications the satellite they launch will deliver).

Question 5: What is the extent of your organisations' role(s) in the value chain? Which satellite applications (as summarised in Table 1 in section 3) does your organisation:
- *use;*
- *provide: or*
- *help to deliver?*

Please list all applications that apply and your role in each in your response.

Spectrum uses and current situation

4.8 We have set out, in section 3, a broad overview of the applications that are provided by the satellite sector, and the ITU service categories to which these relate.

4.9 One of the challenges in understanding the sector from a national regulatory perspective is the inherently cross border nature of satellite service delivery. When considering satellite demand for spectrum in the UK, it is not always sufficient simply to understand the demand that comes solely from the UK. We also need to consider the demand that originates from other countries within the coverage area of a satellite. This may extend to the rest of Europe or, indeed, to even larger geographical areas.

4.10 A further complicating factor is that the use of spectrum for satellite services is often licence exempt or does not require any authorisation, so the information we have access to on current use can be limited.

4.11 To ensure that our analysis takes into account all satellite use, we are seeking qualitative, and where appropriate quantitative, information on the range of applications used in the UK, in Europe and, where relevant, more widely.

Question 6: For each of the satellite applications you use, provide or help deliver (as identified in Question 5), and taking into account your role in the value chain, where applicable please provide:

- *the specific spectrum frequency ranges used for each application, distinguishing between the frequencies used for service provision, for the feeder / backhaul links and for TT&C ;*
- *the coverage area for services links; or, in the case of TT&C and feeder / backhaul links, the location of the gateway station(s);*
- *the estimated number of users (e.g. MSS terminals, DTH subscribers, FSS earth stations);*
- *an estimate of the average use by end user (for those applications for which the demand for spectrum is driven by end user traffic); and*
- *for applications for which the demand for spectrum is driven by other factors, please state what the factor is and the scale of the factor (e.g. for DTH TV the number of TV channels broadcast by format).*

Please provide your response with respect to the UK, the rest of Europe, and other parts of the world where this may be relevant to UK use.

Question 7: For each of the satellite applications you provide, please could you indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

Future demand and supply trends

4.12 We are interested in both high level trends that could shape the sector going forward, as well as trends that relate to specific satellite applications. High level trends could be driven by market and/or technology developments such as growing use of nano and pico-satellites and the potential for High Altitude Platforms[11] to offer an alternative to satellites in some situations.

Question 8: From your perspective, what high level trends will affect the satellite sector in the coming years?

4.13 Factors driving demand specific applications may include the increasing importance placed by European governments and the EU on the universal availability of broadband services and the potential use of spectrum allocated to the FSS to control UAVs. On the other hand, the demand for some satellite applications might decline, for example if there are sufficient improvements to the coverage and/or quality of terrestrial services in the future so that satellites no longer offer a superior service.

Question 9: For each of the satellite applications you use, provide or help deliver what do you see as the a) current demand trends; and b) underlying current and likely future drivers of demand for the satellite application(s) your organisation uses or provides?

[11] 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

Please include in your response for both a) and b) above:
- *the scale and future impact of the trends/drivers on demand;*
- *any variations in the type and scale of trends/drivers by geography (i.e. in the UK, the rest of Europe, and other parts of the world where this may be relevant to UK use) and why;*
- *whether future demand is expected to be temporary or intermittent, and the reasons for this.*

In your response, please provide any evidence which supports your position on the drivers of demand (e.g. forecasts, studies and statistics).

Question 10: Taking into account the drivers you have identified in your response to Question 9 above, what (if any) challenges is your organisation concerned about in meeting potential future demand? Please provide the information by application and band, along with any supporting evidence, if available.

Potential mitigations

4.14 Potential mitigations which might lead to more efficient use of spectrum to help address future demand requirements could include (but need not be limited to):

- improvements to satellite antenna beam focusing technologies. These would enable a satellite to use smaller beams so that frequency bands can be re-used through geographical discrimination, thereby increasing the capacity of the satellite (for example the use of high throughput satellites);

- new transmitter and receiver technologies and standards that could enable better use of spectrum. These include innovative and more spectrally efficient waveforms, better compression techniques and techniques to filter out unwanted signals;

- increasing the efficiency by which satellite networks share spectrum resources with other users (e.g. terrestrial applications);

- changes to satellite network parameters, such as the minimum diameter of the transmitting earth station or limits on the power flux density radiated towards other satellites, that could reduce the orbital separation between GSO satellites;

- greater utilisation of existing available orbital slots through better co-ordination between satellite networks. This may lead to a higher proportion of actual satellites deployed compared to the total number of satellites filed with the ITU, some of which may be just “paper-satellites”.

4.15 In addition to using spectrum more efficiently, in principle it might be possible to make additional spectrum available for satellite applications, for example through the use of new technology to access higher (currently unused) frequencies or repurposing spectrum from other, lower value uses.

Question 11: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? E.g. what order of magnitude increase in frequency re-use might be achieved? To what extent do you believe that these mitigations apply only to certain applications?

Question 12: What other mitigation opportunities do you foresee that we should consider? For what applications are these likely to be applicable and what scale of improvement are they likely to deliver?

Implications for Ofcom

4.16 As highlighted in our approach set out in section 2, this review will help us refine our understanding of the sector, and depending on our findings we will consider what regulatory action(s), if any, we should take.

Question 13: Beyond the activities already initiated and planned for the satellite sector (e.g. as part of WRC-15), do you think there is a need for additional regulatory action that may, for example, help your organisation to address the challenges it faces?

In your response, please indicate what type of action you consider may be needed and why, including any evidence to support your view.

Section 5

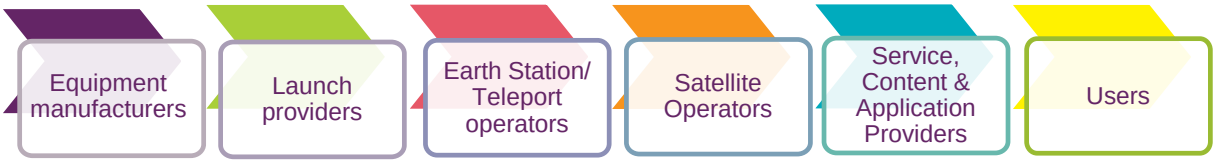
Refining our understanding of the space science sector

5.1 This section discusses a number of areas where additional information about the space science sector would help inform our review. The section invites stakeholders to answer questions about the sector's value chain, current spectrum use, future demand and supply trends, potential mitigations for changing spectrum requirements, and the potential implications for Ofcom.

Value chain for the space science sector

5.2 We believe that the value chain for the space science sector is in principle very similar to the satellite sector; albeit with different organisations involved in many steps of the value chain.

Figure 3: Space science sector value chain



5.3 The various components of the value chain can be described as follows:

- *Equipment manufacturers:* manufacturers of all equipment used in the delivery of space science services from satellites, launchers and earth stations. In general these are the same as for the satellite sector;
- *Launch providers:* companies that offer launch facilities for both GSO and non-GSO satellites providing space science applications. Again, these are generally the same as for the satellite sector;
- *Earth station operators:* organisations that manage and operate earth stations to communicate directly with the space science satellites and other space-bound man-made objects, or receive radio emissions from celestial bodies. Some of these organisations may be the same commercial bodies that operate in the satellite sector, but they also include organisations like the Met Office and the European Space Agency (ESA);
- *Satellite operators:* companies that procure and operate the space science satellites. These are usually publicly funded organisations including the ESA, EUMETSAT and NASA. They generally provide the scientific data collected by the satellites to other organisations at no cost;
- *Service, content and application providers:* entities that collect data and make it available to others. Examples include the Met Office, which provides a wide range of meteorological services, and research bodies, which make available research based on space science data.

- *Users:* end users of the applications and content based on data received from space science use. There are a very wide range of end users, including the general public use of weather forecasts, public sector organisations and businesses (including the aviation sector) that make use of specialised meteorological services, and government departments that are informed by the findings of scientific research, for example on climate change.

5.4 As with any value chain, we understand that individual companies may play more than one role in the value chain.

Question 14: Do you have any comments on our representation of the value chain for the space science sector? How do you think industry revenues are broken down between players at different positions in the chain?

5.5 We are seeking stakeholders' input and views to better understand the roles of the players in each component of the value chain. This will help us to contextualise the responses we receive from individual stakeholders given their specific role(s) in the value chain.

Question 15: What is the extent of your organisations' role(s) in the value chain? Which space science applications (as summarised in Table 2 in section 3) does your organisation:
- *use;*
- *provide; or*
- *help to deliver?*

Please list all applications that apply and your role in each in your response.

5.6 We also appreciate that different players in the value chain will have a different perspective on the space science sector and that some players may have little or no visibility of the individual applications that are delivered (e.g. launch providers may have limited knowledge of the type of science applications the satellite they launch will deliver).

Spectrum uses and current situation

5.7 One of the challenges in carrying out this review derives from the fact that satellite uses of spectrum for space science services do not usually require our authorisation. Even if the services are active rather than passive, such as satellite-mounted radar based applications, these transmissions fall outside UK jurisdiction. As a result, we hold limited information on spectrum use by space science as a result of our role in spectrum authorisation.

5.8 In addition, most EESS satellite constellations are in non-GSO orbits and so move across the surface of the Earth collecting data from different parts of the world. As such, in order to collect data on a global basis they rely on global harmonisation of the frequencies they use. Therefore, to ensure that our analysis considers all relevant space science users, beyond just those we authorise in the UK, we are seeking qualitative, and where possible, quantitative and information on the range of services and applications operating in the UK and overseas.

Question 16: For each of the space science applications you use, provide or help deliver (as identified in Question 15), and taking into account your role in the value chain, where applicable please provide:
- *the specific spectrum frequencies used, distinguishing between the frequencies used for the science application, the frequencies use for downlinking data and, for TT&C;*
- *whether the application is limited to use of specific frequencies and why (e.g. due to fundamental characteristics of the phenomena being measured and/or availability of technology designed for that frequency);*
- *whether the applications use continuous or intermittent measurements;*
- *the typical resolution and associated measurement bandwidths, including an indication of any implication for spectrum requirements;*
- *the geography this use extends over (e.g. land or sea, and regional or global);*
- *the location of the gateway station(s) for TT&C and downlinking data;*
- *the estimated number of users.*

Question 17: For each of the space science applications you provide, please could you indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

Future demand and supply trends

5.9 We are interested in both high level trends that could shape the sector going forward, as well as trends that relate to specific applications. High level trends could be driven by market and/or technology developments, or the growing importance of public policy issues (e.g. flooding) for which space science provides important evidence.

Question 18: From your perspective, what high level trends will affect the space science sector in the coming years?

5.10 It is particularly important to understand changing spectrum demands in this sector as earth sensing and radio astronomy typically depend on access to spectrum nationally and globally that is sufficiently clear from interference to allow reliable and accurate observation. These applications often use spectrum allocated on an exclusive basis and do not share with other (active) services.[12] In addition, the frequencies suitable for some sensing applications are limited by the physical properties of the Earth's surface, atmosphere and natural radiation.

Question 19: For each of the space science application(s) your organisation uses or provides, what are the a) current trends; and b) likely future drivers of demand for spectrum?

Please include in your response:
- *the scale of the demand drivers;*
- *the reason for additional demand (e.g. higher resolution radar data rates/bandwidth required) and whether this increased demand is for data delivery or for the taking of measurements;*
- *whether increased demand can only be met at specific frequencies and why;*
- *any variations in demand drivers by geography (i.e. regional or global), and why; and*

[12] ITU footnote RR 5.340 lists all passive bands in which all emissions are prohibited

- *whether future demand is expected to be temporary or intermittent, and the reasons for this.*

In your response, please provide any evidence which supports your position on the drivers of demand (e.g. forecasts, studies and statistics).

Question 20: Taking into account the drivers you have identified in your response to Question 19 above, what (if any) challenges is your organisation concerned about in meeting potential future demand? Please provide the information by application and band, along with any supporting evidence, if available.

5.11 There may also be developments that could reduce the demand for spectrum in UK. For example, the square kilometre array (SKA) is an international project to build the world's most powerful radio astronomy sites, located in Australia and South Africa. It is possible that spectrum requirements at UK radio astronomy sites may change once UK radio astronomers have access to the much more powerful SKA sites.

Question 21: Are there any future developments, such as the radio astronomy SKA, that could reduce the demand for space science spectrum in the UK?

Potential mitigations

5.12 As noted above many space science applications need access to spectrum that is sufficiently clear from interference to allow reliable and accurate observation, and this is often achieved by using spectrum on an exclusive basis. However, given the growing demand on spectrum from many different sectors it may be increasingly difficult to identify exclusive bands for space science use.

5.13 We are therefore particularly interested in potential developments that could help mitigate this challenge by facilitating greater sharing between space science use and other users, both in-band and in adjacent bands. For example, potential techniques may include (but need not be limited to):

- implementation of better EESS receiver filtering and/or sensor design to improve EESS compatibility with services in adjacent bands;
- development of new signal processing techniques to reduce the susceptibility of space science applications to interference;
- a global database of science satellites (including information such as orbital details, repeat period etc.) that might enable sharing with other spectrum users whilst avoiding those users causing interference to science satellites; and
- better coordination between space science users and commercial spectrum users leading to greater geographic sharing of spectrum between these users, for example where frequencies used by radio astronomy sites can, with appropriate separation distances, be re-used for commercial co-ordination between radio astronomy sites.

Question 22: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? To what extent do you believe that these mitigations apply only to certain applications?

Question 23: What other mitigation opportunities do you foresee that we should consider? For what applications are these likely to be applicable and what scale of improvement are they likely to deliver?

Implications for Ofcom

5.14 As highlighted in our approach set out in section 2, this review will help us refine our understanding of the sector, and depending on our findings we will consider what regulatory action(s), if any, we should take.

Question 24: Beyond the activities already initiated and planned for the space science sector (e.g. as part of WRC-15), do you think there is a need for additional regulatory action that may, for example, help your organisation to address the challenges it faces?

In your response, please indicate what type of action you consider may be needed and why, including any evidence to support your view.

Section 6

Next steps

6.1 Following the publication of this CFI, we will be hosting two half-day workshops, one for each of the two sectors addressed in this document.

6.2 We intend to use these workshops to clarify with stakeholders the purpose of our satellite and space science review, to expand stakeholders' understanding of the type of information we are seeking, and to give stakeholders from both sectors the opportunity to engage with us to provide better insight into the current and potential future use of spectrum.

- the Satellite workshop will be held on **Friday 3 July**.
- the Space Science workshop will be held on **Friday 10 July**.

6.3 To register your interest in attending either workshop, please email SSSWorkshop@ofcom.org.uk, specifying your sector(s) of interest (satellite or space science) in the subject line.

6.4 For the next phase of our satellite and space science review, we intend to develop our view of the trends and drivers affecting these sectors and their implications for spectrum use. We expect to provide an update of our findings in early 2016.

Annex 1

Responding to this CFI

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 13 August 2015**.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/space-science-cfi/howtorespond/form, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email SSSreview@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

James Richardson
Floor 3
Riverside House
2A Southwark Bridge Road
London SE1 9HA

Fax: 020 7981 3333

A1.4 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.5 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.6 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact James Richardson on 020 7981 3154 or email james.richardson@ofcom.org.uk.

Confidentiality

A1.7 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether

all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.8 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.9 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/terms-of-use/

Next steps

A1.10 Following the end of the consultation period, Ofcom intends to publish an update on our findings in early 2016.

A1.11 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/email-updates/.

Ofcom's consultation processes

A1.12 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.13 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.14 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. 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

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at http://stakeholders.ofcom.org.uk/consultations/consultation-response-coversheet/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

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 ☐

Whole response ☐

Part of the response ☐

Name/contact details/job title ☐

Organisation ☐

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 seeks to publish responses on receipt. 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)

Annex 4

Consultation questions

A4.1 The questions in this CFI may not be relevant to all stakeholders. We have therefore grouped them below into those which are directed at:

- all respondents;
- respondents from the satellite sector; and
- respondents from the space science sector.

A4.2 The workshops we are holding in July will provide a further opportunity for us to clarify any questions stakeholders have about how best to respond to specific questions, taking into account their position in the value chain and the types of applications they provide.

All respondents

Question 1: Do you have any comments on our approach to this review?

Satellite respondents

Question 2: Do you have any comments on our broad overview of the satellite sector set out in this section? In particular, do you have comments on the completeness of the list of applications, their definitions and their use of the relevant ITU radiocommunications service(s)?

Question 4: Do you have any comments on our representation of the value chain for the satellite sector? How do you think industry revenues are broken down between players at different positions in the chain?

Question 5: What is the extent of your organisations' role(s) in the value chain? Which satellite applications (as summarised in Table 1 in section 3) does your organisation:
- *use;*
- *provide: or*
- *help to deliver?*

Please list all applications that apply and your role in each in your response.

Question 6: For each of the satellite applications you use, provide or help deliver (as identified in Question 5), and taking into account your role in the value chain, where applicable please provide:
- *the specific spectrum frequency ranges used for each application, distinguishing between the frequencies used for service provision, for the feeder / backhaul links and for TT&C ;*
- *the coverage area for services links; or, in the case of TT&C and feeder / backhaul links, the location of the gateway station(s);*
- *the estimated number of users (e.g. MSS terminals, DTH subscribers, FSS earth stations);*
- *an estimate of the average use by end user (for those applications for which the demand for spectrum is driven by end user traffic); and*

- *for applications for which the demand for spectrum is driven by other factors, please state what the factor is and the scale of the factor (e.g. for DTH TV the number of TV channels broadcast by format).*

Please provide your response with respect to the UK, the rest of Europe, and other parts of the world where this may be relevant to UK use.

Question 7: For each of the satellite applications you provide, please could indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

Question 8: From your perspective, what high level trends will affect the satellite sector in the coming years?

Question 9: For each of the satellite applications you use, provide or help deliver what do you see as the a) current demand trends; and b) underlying current and likely future drivers of demand for the satellite application(s) your organisation uses or provides?

Please include in your response for both a) and b) above:

- *the scale and future impact of the trends/drivers on demand;*
- *any variations in the type and scale of trends/drivers by geography (i.e. in the UK, the rest of Europe, and other parts of the world where this may be relevant to UK use) and why;*
- *whether future demand is expected to be temporary or intermittent, and the reasons for this.*

In your response, please provide any evidence which supports your position on the drivers of demand (e.g. forecasts, studies and statistics).

Question 10: Taking into account the drivers you have identified in your response to Question 9 above, what (if any) challenges is your organisation concerned about in meeting potential future demand? Please provide the information by application and band, along with any supporting evidence, if available.

Question 11: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? E.g. what order of magnitude increase in frequency re-use might be achieved? To what extent do you believe that these mitigations apply only to certain applications?

Question 12: What other mitigation opportunities do you foresee that we should consider? For what applications are these likely to be applicable and what scale of improvement are they likely to deliver?

Question 13: Beyond the activities already initiated and planned for the satellite sector (e.g. as part of WRC-15), do you think there is a need for additional regulatory action that may, for example, help your organisation to address the challenges it faces?

In your response, please indicate what type of action you consider may be needed and why, including any evidence to support your view.

Space science respondents

Question 3: Do you have any comments on our broad overview of the space science sector? In particular, do you have comments on the completeness of the list of applications, their definitions and their use of the relevant radiocommunications service(s)?

Question 14: Do you have any comments on our representation of the value chain for the space science sector? How do you think industry revenues are broken down between players at different positions in the chain?

Question 15: What is the extent of your organisations' role(s) in the value chain? Which space science applications (as summarised in Table 2 in section 3) does your organisation:
- *use;*
- *provide; or*
- *help to deliver?*

Please list all applications that apply and your role in each in your response.

Question 16: For each of the space science applications you use, provide or help deliver (as identified in Question 15), and taking into account your role in the value chain, where applicable please provide:
- *the specific spectrum frequencies used, distinguishing between the frequencies used for the science application, the frequencies use for downlinking data and, for TT&C;*
- *whether the application is limited to use of specific frequencies and why (e.g. due to fundamental characteristics of the phenomena being measured and/or availability of technology designed for that frequency);*
- *whether the applications use continuous or intermittent measurements;*
- *the typical resolution and associated measurement bandwidths, including an indication of any implication for spectrum requirements;*
- *the geography this use extends over (e.g. land or sea, and regional or global);*
- *the location of the gateway station(s) for TT&C and downlinking data;*
- *the estimated number of users.*

Question 17: For each of the space science applications you provide, please could you indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

Question 18: From your perspective, what high level trends will affect the space science sector in the coming years?

Question 19: For each of the space science application(s) your organisation uses or provides, what are the a) current trends; and b) likely future drivers of demand for spectrum?

Please include in your response:
- *the scale of the demand drivers;*
- *the reason for additional demand (e.g. higher resolution radar data rates/bandwidth required) and whether this increased demand is for data delivery or for the taking of measurements;*
- *whether increased demand can only be met at specific frequencies and why;*

- *any variations in demand drivers by geography (i.e. regional or global), and why; and*
- *whether future demand is expected to be temporary or intermittent, and the reasons for this.*

In your response, please provide any evidence which supports your position on the drivers of demand (e.g. forecasts, studies and statistics).

Question 20: Taking into account the drivers you have identified in your response to Question 19 above, what (if any) challenges is your organisation concerned about in meeting potential future demand? Please provide the information by application and band, along with any supporting evidence, if available.

Question 21: Are there any future developments, such as the radio astronomy SKA, that could reduce the demand for space science spectrum in the UK?

Question 22: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? To what extent do you believe that these mitigations apply only to certain applications?

Question 23: What other mitigation opportunities do you foresee that we should consider? For what applications are these likely to be applicable and what scale of improvement are they likely to deliver?

Question 24: Beyond the activities already initiated and planned for the space science sector (e.g. as part of WRC-15), do you think there is a need for additional regulatory action that may, for example, help your organisation to address the challenges it faces?

In your response, please indicate what type of action you consider may be needed and why, including any evidence to support your view.

Annex 5

Glossary

5G	Fifth generation mobile phone standards and technology
AMS(R)S	Aeronautical Mobile Satellite (Route) Service. A particular type of AMSS reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes
AMSS	Aeronautical Mobile Satellite Service. A particular type of MSS for which the earth stations are located on board aircraft.
BSS	Broadcasting Satellite Service. One-way transmission of high-power broadcast signals by GSO satellites directly to consumers, who receive the signals on locally installed antenna equipment (e.g. satellite dishes).
C-band	Spectrum frequencies commonly in the ranges around 6 GHz (Earth-to-space) and around 4 GHz (space-to-Earth)
CEPT	European Conference of Postal and Telecommunications Administrations
CFI	Call for Input
COTM	Communications on the move
COTP	Communications on the pause
DTH	Direct to Home. Involves the reception of television signals directly from satellites.
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.
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.

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.
Galileo	Europe's satellite navigation system (similar to GPS) under civilian control
GHz	Gigahertz. A unit of frequency of one billion cycles per second.
GMDSS	Global Maritime Distress and Safety System. A particular system operating under the MMSS providing communication services to people in distress.
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.
HTS	High Throughput Satellite. Satellites that typically employ frequency re-use techniques to increase their overall throughput.
IMT	International Mobile Telecommunications. The ITU term that encompasses 3G, 4G and 5G wireless broadband systems.
IPTV	Internet Protocol Television. The term used for television and/or video signals that are delivered to subscribers or viewers using internet protocol (IP), the technology that is generally used to access the internet.
ISS	Inter Satellite Service. Two-way transmission of signals between two or more satellites. Typically these are used for non-GSO constellations of satellites to relay transmissions between individual satellites.

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
ITU-R Region 1	Article 5 of the ITU Radio Regulations divides the world into three regions for the allocation of frequencies. Region 1 includes Europe, Africa, parts of the Middle East, the former Soviet Union and Mongolia.
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)
L-band	Spectrum frequencies commonly in the ranges around 1.5 GHz (space-to-Earth and Earth-to-space)
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.
MEO	Medium Earth Orbit. MEO satellites orbit the earth at heights of around 10,000 km above the Earth's surface.
MetSat service	Meteorological Satellite Service. A type of earth exploration-satellite service for meteorological purposes.
MHz	Megahertz. A unit of frequency of one million cycles per second.
MMSS	Maritime Mobile Satellite Service. A particular type of MSS for which user terminals are located on board ships.
MSS	Mobile Satellite Service. Two-way communication links between portable user terminals and one or more satellites.
non-GSO	Non-geostationary satellite orbit
Ofcom	Independent regulator and competition authority for the UK communications industries
Orbital arc	An imaginary line tracing all positions along a given orbit

Orbital separation	The angular separation between two satellites on a given orbit
Orbital slots	The orbital position of satellites, typically on the geostationary satellite orbit
QoS	Quality of service is the overall performance of a network, particularly the performance seen by the users of the network.
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.
RED	Radio Equipment Directive
RNSS	Radionavigation Satellite Service. One-way transmission of signals from constellations of satellites towards the Earth. The coded and time-stamped signals are used to determine the position and velocity of receive-only terminals on the Earth and to synchronise other devices to a single time reference. GPS and Galileo operate under this service.
ROES	Receive-Only Earth Station. A satellite earth station which receives radio signals but does not transmit.
RR	Radio Regulations
SAR	Synthetic Aperture Radar is used for creating radar images by transmitting a high power radio signal and analysing the echo.
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 radioastronomy sites, located in Australia and South Africa, with its headquarters based at Jodrell Bank observatory in the UK.
SMOS	Soil Moisture and Ocean Salinity
SMS	Spectrum Management Strategy, published by Ofcom on 30 April 2014
SRS	Space Research Service. A service for studying the physical characteristics of other celestial bodies including planets.

Teleport	A physical site usually owned by a single company where a relatively large number of earth stations are co-located
TT&C	Telemetry, Telecommand and Control. 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).
UAVs	Unmanned Aerial Vehicle
UK2	Except by special agreement having the approval of the NFPG this frequency band, or the allocation to this radio service, is reserved exclusively for military use
VSAT	Very Small Aperture Terminal. A satellite earth station equipped with an antenna of relatively small size.
WRC	World Radiocommunication Conference. The WRC reviews and revises the Radio Regulations. They are held every three to four years. The last three conferences were held in 2003, 2007 and 2012. The next WRC will be held in Geneva in November 2015 and is referred to as WRC-15.
xDSL	Refers collectively to all types of digital subscriber lines, the two main categories being Asymmetric DSL (ADSL) and Symmetric DSL (SDSL). Two other types of xDSL technologies are High-data-rate DSL (HDSL) and Very high data rate DSL (VDSL).