Ofcom Call for Input (CFI) –
"Spectrum above 6 GHz for future mobile communications"

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Draft ESOA Response for Ofcom Call for Input (CFI)

Introduction and Summary

The European Satellite Operators Association (ESOA) welcomes the Ofcom Call for Input (CFI) effort to study the scope for frequencies above 6 GHz to facilitate the development of new mobile radio services known as 5G.

It was evident from answers already received to the Ofcom initial consultation on WRC-2015 / Q.44 that identification of additional spectrum for new radio services such as 5G / IMT should not result in detrimental effects on existing radio services including space services / satellite services. Existing satellite services, such as fixed satellite service (FSS), broadcast satellite service (BSS) and mobile-satellite service (MSS), are thriving and enable important capabilities, including TV and radio services to millions of household in the UK and hundreds of millions in Europe and beyond, critical public safety communications during natural disasters and emergencies and cost-effective communications in urban, sub-urban, rural or remote areas, including but not only where terrestrial infrastructure may be unavailable. Moreover, these existing satellite services are expanding and exploring innovative new uses, including, for example, the use of the Ku-bands and Ka-bands for providing High Throughput Satellite (HTS) services enhancing the provision of video and data services to consumers. Ofcom also should take into consideration that the very same satellite services are already being considered within the ITU-R Working Party 5D to be part of the vision of 5G eco-system.

ESOA notes with significant concern that the focus of some 5G proponents for 5G spectrum identification seems to be at frequencies used for key satellite services, notably in C-band[1], Ku Band[2] and Ka-band[3]. ESOA considers that any IMT / 5G terrestrial use of Ku-band will inevitably disrupt not only critical incumbent TV services across Britain but also existing and future VSAT services in the C band and Ku Band for both fixed and mobility applications, thus jeopardizing the billions[4] of pounds in investments and revenues from these investments. More fundamentally, it will severely harm the reputation of the UK as a dependable place of doing business, founded on long term regulatory stability and predictability. ESOA also considers that the entry of IMT / 5G terrestrial use into Ka-band will likely disrupt critical incumbent Ka-band satellite services within the 27.5 – 31.0 / 17.3 – 22.0 GHz bands and will jeopardize the already billions[5] of pounds in investments and, perhaps more importantly, harm UK investment in the space sector by diminishing the regulatory certainty currently in place for Ka-band satellite systems. In addition, many satellite system

[1] C band refers in general to frequency roughly in 3 – 4 GHz downlink and 6 – 7 GHz uplink
[2] Ku band refers in general to frequencies roughly in 10.7 – 12.75 GHz downlink and 12.75 – 14.5 GHz uplink
[3] Ka band refers in general to frequencies roughly in 17 – 22 GHz downlink and 24 – 31 GHz uplink
[4] In 2013, subscription to broadband service grew 20%, and such services generated revenues of nearly $2 billion/year. See Satellite Industry Association, 2014 State of the Satellite Industry Report at 12 (Sep. 2014), available at http://siaorg.siteprotect.net/wp content/uploads/2014/09/SSIR-September- 2014-Update.pdf
[5] In 2013, subscription to broadband service grew 20%, and such services generated revenues of nearly $2 billion/year. See Satellite Industry Association, 2014 State of the Satellite Industry Report at 12 (Sep. 2014), available at http://siaorg.siteprotect.net/wp content/uploads/2014/09/SSIR-September- 2014-Update.pdf

operators are making investments higher frequency bands, including the core Q/V-bands[6]. Fundamentally, identifying frequencies used for satellite services for 5G technologies will severely harm the reputation of the UK as a dependable place of doing business, founded on long term regulatory stability and predictability.

If a future ITU WRC agrees an agenda item for the identification for IMT / 5G terrestrial use, Ofcom should ensure that such an agenda item is limited in scope to frequency bands above 31 GHz.

The trend towards higher frequency bands is reflected in various stakeholders' replies and to the recent FCC 'Spectrum Frontiers' notice of inquiry (NOI) [7] focused on finding wide bands of contiguous blocks of spectrum ranging from multiple hundreds of MHz to multiple GHz[8]. Furthermore based on the comments received by most stakeholders in various national consultations, it can be shown that more viable opportunities to accommodate IMT/ 5G services exist in higher millimetre wave (mmWave) frequencies above 31.0 GHz than in lower sub-mmWave bands.

Question 1: Are there practical ways of achieving the very high performance that use of wide channels above 6 GHz could offer, for example using carrier aggregation of lower frequency bands?

The radio communication research community is focusing on 5G as a major topic for the next years to come. In the current stage of research, most of the technical aspects are about 5G spectrum availability and usage, and include consideration, for example, of whether carrier aggregation is useful. The nature of the basic access to the physical channel is being addressed from the very beginning along with the technical components, since its availability and usage mechanisms will shape the future developments for 5G.

ESOA notes that carrier aggregation is an emerging standardised technology already being deployed for legacy 4G LTE networks operating in relevant bands below 1 GHz and between 1.5 GHz and 2.7 GHz with the aim to achieve user data rates in the order of 10s of Mbps. However, ESOA does not believe that carrier aggregation is a relevant or practical solution for the entirely new user experience that 5G will provide through the provision of very high user data rates (up to 1 Gbps or even more). Such new experience will require effective total bandwidths of several GHz (up to at least a GHz per user, and multiple GHz to support multiple operators). Mobile equipment vendors have reported cost concerns related to carrier aggregation for such aggregate bandwidths and wide range of carrier frequencies. 5G PPP also advocates the use of contiguous wideband carrier frequencies for the support of the new and unique 5G experience.

One of the most developed and independent studies looking at the expected spectrum scenarios resulting from perceived spectrum needs for 5G comes from the EU project METIS[9]. The main objective of the project is to lay the foundation of 5G, the next generation mobile and wireless communications system. The consortium consisted of mobile manufacturers, telecommunications operators, academic institutions, automotive industry and research centres. The availability of frequency bands with sufficiently large

[6] V-band, in general, is 40 – 75 GHz. In particular, the FSS V-band is 37.5 – 40.5 GHz downlink and 42.5 – 43.5 GHz uplink

[7] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Notice of Inquiry, FCC 14-154 (rel. Oct. 17, 2014)

[8] "It would be desirable to secure at least 500 MHz of bandwidth, and 1 GHz or more bandwidth" (source: Samsung page 11) // "Huawei believes, will require contiguous channel bandwidths in excess of 1-2 GHz available within each access network" (Source Huawei page 11) // "To accommodate very large channel bandwidths and to support carrier aggregation of spectrum bands, Motorola Mobility agrees with the suggestion in the Notice that new bands ideally should be 1 to 2 GHz wide" (Source Motorola page 9) // "Licensees will therefore be incentivized to obtain licenses with a large amount of bandwidth (between 500 MHz and 1 GHz)" (source T-Mobile Page 9) // "A number of the bands identified in the NOI have 500 MHz or greater channel Bandwidth" (Source Qualcomm page 17) // "The other approach consists in using much larger bandwidth (e.g., 2GHz) of contiguous spectrum to achieve maximum data throughputs of 10 Gbps" (source Nokia page 13)

[9] METIS_D5.3_v1, Section 2.5 (Document Number: ICT-317669-METIS/D5.3, dated 29-August-2014

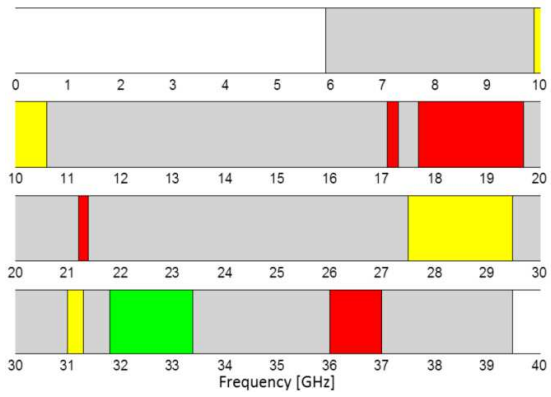
bandwidth for future 5G systems will be one of the main topics which will have a direct impact on the system Total Cost of Ownership (TCO), and will therefore determine the commercial and economic viability. Spectrum demand is strongly related to network deployment and foreseen scenarios in terms of traffic demand.

In the EU METIS project assessments of the spectrum range 380 MHz – 275 GHz were performed. In particular, the range 5.925 – 95 GHz was assessed in detail and with respect to the possibility of operating a 5G system in the various bands. The assessment took into consideration the current regulation applied in the band, with emphasis on the European situation (including the UK), as well as the physical propagation properties of the bands. The applied methodology and assessment emphasized short range usage for 5G/IMT. The summary of this band assessment is reproduced in Figure 1 below, in which high priority bands are those that are more favourable from regulation and technical point of view for accommodation of future 5G / IMT.

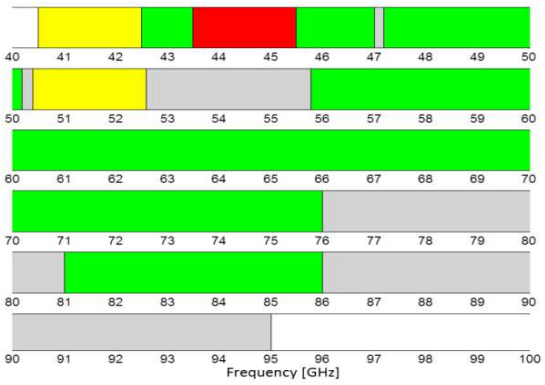
From Figure 1, it can be seen that the EU METIS study has clearly identified that mmWave frequencies from 31 GHz to 86 GHz would be particularly suitable for access, front-hauling and backhauling, as well as for short range 5G links. More opportunities are expected to exist in higher mmWave frequencies above 31 GHz than in sub-mmWave bands below 31 GHz for accommodation of 5G. This is due to the increased isolation between co-existing terrestrial radio systems that follows from the propagation properties in higher bands, where the assessment focused on finding wide bands of contiguous spectrum (up to 1 GHz and even above). Such bands are difficult to find in lower frequencies due to current regulation and already existing intensive utilisation and expected planned usage and associated investments by other radio services (e.g terrestrial and satellite/space services). The need for higher bandwidths is also backed by one of the world leaders in 5G research and trials Samsung, which stated in its FCC Comments:

"*It would be desirable to secure at least 500 MHz of bandwidth, and 1 GHz or more bandwidth would be preferable as many applications (like virtual reality) will require this amount of spectrum to deliver the capacity and data rates desired. For this reason, as explained below, higher frequency bands would be very well-suited for the provision of these services".* [10]

The EU funded METIS program identified various frequency bands above 31 GHz as 'high priority' candidates for the future accommodation of 5G IMT service which are envisaged by their proponents to require wide contiguous segment of frequencies (typically > 500 MHz). It is interesting to note that Ericsson and Huawei are both members within this study. ESOA encourages Ofcom to take good note of the findings of this report by the METIS program and consider the METIS evaluation for suitable candidate bands for 5G / IMT. All "High priority" bands are above 31 GHz.



Overview of spectrum opportunities for 5.925 - 40.5 GHz



Overview of spectrum opportunities for 40.5 – 100 GHz

[10] Comments of Samsung Electronics America, Inc. and Samsung Research America, FCC GN Docket No. 14-177, RM-11664, at 8 (Jan. 15, 2015)

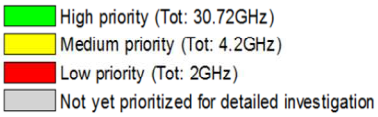


Figure 1: METIS Study

Question 2: What recent or emerging advances in technology may provide effective solutions to the challenges in higher frequency bands? For example can increased propagation losses be mitigated by using the high gains available with massive MIMO?

Technological advances in beamforming, phased antenna array deployment in mobile devices, and other areas have made the use of mmWave spectrum for mobile broadband achievable. Samsung has already determined that a low-power base station can provide 1 Gbps service using 1 GHz of bandwidth for outdoor at either 28 GHz or 38 GHz[11] over a cell radius of tens to hundreds of metres. Thus 5G services in the millimeter wave bands above 31 GHz spectrum are achievable and operators can realistically deploy cells sufficient to provide seamless coverage.

Moreover, beamforming techniques—which are feasible for relatively small antenna arrays at these high frequencies—can mitigate propagation loss. To achieve this large directional gain to overcome the path loss inherent to mmWave spectrum, beamforming with a phased antenna array must be employed. Because of the small wavelength of millimeter wave signals, phased array antennas are able to offer large beamforming gain while keeping individual antenna elements small and inexpensive. These antennas also enable adaptive alignment of transmit and receive beams electronically.

Furthermore at frequencies above 31 GHz, wavelengths are much shorter, enabling the creation of phased antenna arrays that are much smaller. The benefits of utilizing many dozens of antenna elements in a handset are that each of these individual antennas can be electronically phased to send and receive communications more efficiently and effectively.

Question 3: Are there any fundamental/inherent frequency constraints of the 5G technologies currently being investigated with regard to:

a) minimum contiguous bandwidth per operator? Will the spectrum for multiple operators need to be contiguous (i.e. a single band) or could multiple operators be supported through multiple bands?

b) frequency range over which the technologies are expected to be able to operate, for example due to propagation, availability of electronic components, antenna designs and costs of deployment? For example, is 10-30 GHz better or worse than 30-50 GHz and why?

The Mobile/IMT/5G community is generally seeking access to a contiguous block of bandwidth between high hundreds of MHz up to multiple GHz. Samsung in their comments to the FCC say *"Allocating the large amounts of bandwidth required by 5G will require a significant effort from both the Commission and the global community."* [12]

The bands with the most likelihood of future access and with sufficient spectrum are found above 31 GHz in bands that satellite service is not present or being developed.

[11] S. Hur, et al., "Millimeter-wave Channel Modelling based on Measurements in Inbuilding and Campus Environments at 28 GHz", will be presented on COST IC1004 10th Meeting, May 2014; Y. Chang, et al., "A Novel Two-Slope mmWave Channel Model Using 3D Ray-Tracing Technique in Urban Environments", submitted to IEEE PIMRC 2014; M. K. Samimi, et al., "Ultra-Wideband Statistical Channel Model for Non Line of Sight Millimeter- Wave Urban Channels," submitted to IEEE Globecom 2014

[12] Comments of Samsung Electronics America, Inc. and Samsung Research America, FCC GN Docket No. 14-177, RM-11664, at 9 (Jan. 15, 2015)

One should note that many satellite system operators around the world have made large investments into networks that currently operate or plan to operate global or regional satellite services using C-, X-, Ku-, Ka-, and Q/V-band frequencies. These satellite networks already provide invaluable services in many regions around the world and will continue to grow. These networks are also enablers for global terrestrial operators. Because satellite technology has a long development path, regulatory certainty, as promoted by Ofcom and other regulators across Europe, promotes long-term investments in capital-intensive networks such as satellite systems. Therefore Ofcom should consider proposals to enable 5G services only outside those satellite bands in order to make sure that a stable regulatory environment continues to be available to foster multibillion US dollar worth of investment and development in satellite services and space services. Such careful policy will also support the timely deployment of innovative new 5G services to the public in the UK and beyond.

It is clear that a key objective for 5G/IMT would be to identify a band that is not only available to certain individual countries or regional Administrations, but to find a continuous block of bandwidth which will be possible to harmonise in a global ITU / WRC level. 5G is a global initiative and international harmonization will likely be essential. Any action proposed by Ofcom related to 5G spectrum identification should reflect the need for regional and global harmonization of services. Harmonization allows mobile network operators and equipment vendors to take advantage of economies of scale and other efficiencies, which reduce service costs and benefit users of the service.

Harmonisation is especially important for satellite services, which by their very nature operate across national boundaries. Failure to allow satellite systems to provide regional or global services would lead to inefficiencies in spectrum use and could seriously constrain to satellite operators and satellite service providers. Further, to the extent that satellites are operating globally based on certain assumptions of technical parameters, the introduction of co-primary terrestrial services in the band could affect coordination agreements in a way that negatively impacts satellite operators. It is also very difficult to achieve new allocations to satellite services on a global harmonized basis at ITU / WRC level; hence the ability to use the existing ITU allocations to satellite / space services, especially in the band 3.6 – 31 GHz should not be put at risk.

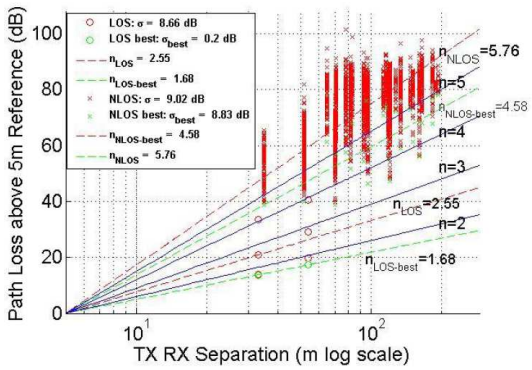
As 5G/IMT intends to utilize cells with a radius less than 200 m, it is feasible for 5G/IMT to close their link budget at frequencies above 31 GHz.

One of the challenges of mobile communications in the higher bands for outdoor access is to overcome the expected propagation conditions. The most obvious obstacle mentioned by Alcatel for example is the higher path loss of the bands above 6 GHz relative to traditional cellular bands. Just looking at free-space path loss, there will be an expected loss based on the frequency used and the distance range, but this challenge is encountered in any frequencies above the traditional mobile frequencies below 2.7 GHz, whether above 6 GHz, or indeed above 31 GHz. To mitigate and compensate for this challenge the major manufacturers (Samsung, Alcatel, Nokia etc.) are reducing the cell radius from kilometres to metres in order to reduce the expected additional losses which can be as high as 30.9 dB[13]. This has the major benefit also of very significantly increasing the overall system capacity, as the spectrum is reused more efficiently as the carrier frequency increases.

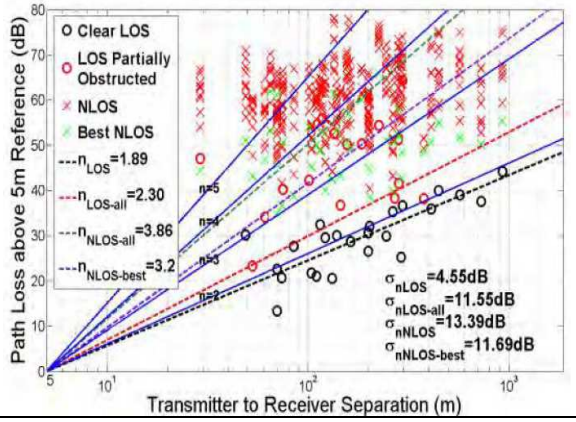
Samsung has deployed an 800 MHz null-to-null bandwidth spread spectrum sliding correlator channel sounder with a carrier frequency of 37.625 GHz with a +22 dBm output power before the TX antenna. A total of 43 TX-RX combinations were measured with up to 12 various antenna configurations for each measurement location. The RX was positioned in a number of LOS, partially obstructed LOS, and NLOS locations representative of an outdoor urban environment including foliage, high-rise buildings, and pedestrian and vehicular traffic and at each receiver locations measurements were acquired and assessed. The path loss was determined for 38 GHz using 13.3 dBi and 25 dBi horn antennas and for all TX locations,

[13] See Comments of Samsung Electronics America, Inc. and Samsung Research America, FCC GN Docket No. 14-177, RM-11664, at Annex B (Jan. 15, 2015)

measurements have yielded path loss between 38 GHz and 28 GHz to be very comparable and even better at 38 GHz. See Figure 2.



Measured path loss values relative to 5 m free space path loss for 28 GHz outdoor cellular channels. These path loss values were measured using a 24.5dBi narrow beam antenna. The antennas were rotated in the azimuth plane, recording measurements at 10degrees incremental steps. The values in the legend represents the path loss exponent of each environment (LOS and NLOS)



Path loss scatter plot using 25 dBi Rx antenna at 38 GHz. LOS and NLOS measurements have path loss exponents of 2.30 (compared to 2.55 at 28 GHz) and 3.86 (compared to 5.76 at 28 GHZ) respectively, while the best NLOS links have a path loss exponent of 3.2.

Figure 2: Propagation characteristics between 28 GHz and 38 GHz

More recently, Samsung testing for 5G achieved speeds of 7.5 Gbps using 800 MHz of bandwidth systems in the 28 GHz band. However based on the above propagation results there is no real technical reason to assume that similar 5G data rates cannot be achieved in bands above 31 GHz comparable to that at 28 GHz. In fact Samsung have identified in their recent submission to the FCC[14] also the 37/42GHz bands as candidate bands for development and implementation for 5G terrestrial systems.

Furthermore Samsung has trialled 5G RLAN systems at circa 61 GHz capable of speeds of 4.6Gbps[15] for indoor use. Therefore it is apparent that such developments in 5G technology would enable viable use of bands of above 31 GHz for supporting future 5G developments and implementations.

From the information summarised above, it is apparent that from the perspective of 5G technology there is no particular preference in the choice of frequency band. However, from the perspective of potential impact on other services, and from the perspective of the feasibility to identify large bandwidths of spectrum required for 5G, there is clear benefit in focussing on higher frequency (millimetre wave) bands.

Question 4: Will 5G systems in higher frequency bands be deployed, and hence need access to spectrum, on a nationwide basis or will they be limited to smaller coverage areas? And if so, what sort of geographic areas will be targeted?

If 5G services are successful, it is likely that they will be deployed over large geographic areas, so that enhanced customer services are available in the majority of cases. This is the pattern seen with the

[14] http://apps.fcc.gov/ecfs/document/view?id=60001013807
[15] http://www.extremetech.com/computing/191872-samsung-develops-60ghz-wifi-capable-of-4-6gbps-will-be-in-devices-next-year)

development of mobile services from 2G, to 3G, to 4G. Even though 4G coverage currently lags behind 3G coverage, it is likely that it will catch up (and possibly exceed 3G coverage) in the coming years. In some cases regulators have imposed coverage obligations on mobile operators, to avoid creating a new "digital divide". Therefore in considering potential bands for 5G, this should be done with the expectation of wide (e.g. national) geographic coverage.

Question 5:

a) To what extent will 5G systems in higher frequency bands need dedicated spectrum on a geographical and/or time basis or can they share?
b) If they can share, what other types of services are they likely to be most compatible with?
c) What technical characteristics and mitigation techniques of 5G technologies could facilitate sharing and compatibility with existing services?
d) Could spectrum channels be technically shared between operators?

The frequency bands above 6 GHz and below 31 GHz are currently intensively used by a large number of services, including satellite communication systems, mostly operating in the C-band, X-band, Ku-band, and Ka-band frequencies. Such use by these radio services, in particular Ka-band satellite systems, is expected to radically increase in coming years

Satellite networks are already designed to efficiently share spectrum with several other spectrum users. For example, satellite systems which do not involve the use of ubiquitous earth stations often also share with certain terrestrial fixed services, typically line of sight fixed links, coordinated on a case-by-case basis. Satellite networks also extensively share with each other much of the same spectrum, employing precise orbital spacing and directional antennas to avoid unacceptable interference into each other.

An important factor identified by Ofcom in the CFI for 5G is that spectrum sharing will enable more efficient use of spectrum. A critical fact to this assumption should be highlighted very clearly from the various comments already received by stakeholders that there remains great doubt about the *feasibility and sustainability* of 5G / IMT systems sharing spectrum with other spectrum users including in particular satellite services.

High density IMT / 5G services would not fit into any existing frequency sharing models and thus are not compatible with the existing intensive use of spectrum between 6 GHz and 31 GHz by satellite services and probably most other services. ESOA is not aware of a prior case where high density mobile service (2G, 3G, 4G) involving ubiquitous deployment of mobile terminals and base stations has ever successfully shared spectrum in the medium to longer term on a sustainable basis with satellite services where satellite earth stations have been ubiquitously deployed.[16] If 5G mobile services are successful, it is inevitable that they will be widely deployed geographically, either to meet commercial demands, or to meet government led requirements for near-universal coverage.

It can thus be seen that IMT systems (and hence 5G), which are high-density by their very nature, cannot share with other services. This explains why mobile operators generally require exclusive licenses for the national deployment of their IMT services in order to protect their long-term investments and the services of their customers.

The relatively short range of communication of such IMT above 6 GHz (in the order of 100s of meters) does not change that premise. The deployment of high density mobile services with such a range on ostensibly shared basis with other allocated radio services eventually and invariably will lead to the displacement in almost all cases of any other radio services (including, but not limited to, satellite services).

[16] See the draft new Report **ITU-R [FSS-IMT C-BAND DOWNLINK]** - *Sharing studies between International Mobile Telecommunication-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15*

To further shed light on the difficult of co-existence between 6 GHz to 31 range, a band assessment with modified assessment criteria was performed by the EU funded METIS study. In this assessment, a reduced target minimal contiguous bandwidth of 60 MHz was used, and a larger focus was given to outdoor deployments. The used criteria represented a situation where a wide area covering 5G system would co-exist with currently deployed systems, such as satellite and terrestrial fixed services in the bands between 6 GHz and 31 GHz. The decreased target bandwidth increases the opportunities significantly, however the outdoor deployments implied more difficultly to co-existence with incumbent services. The resulting assessment summary is given in Figure 3. As can be seen from Figure 3, there were no real opportunities identified by the EU METIS study for accommodation of 5G / IMT below 31 GHz.

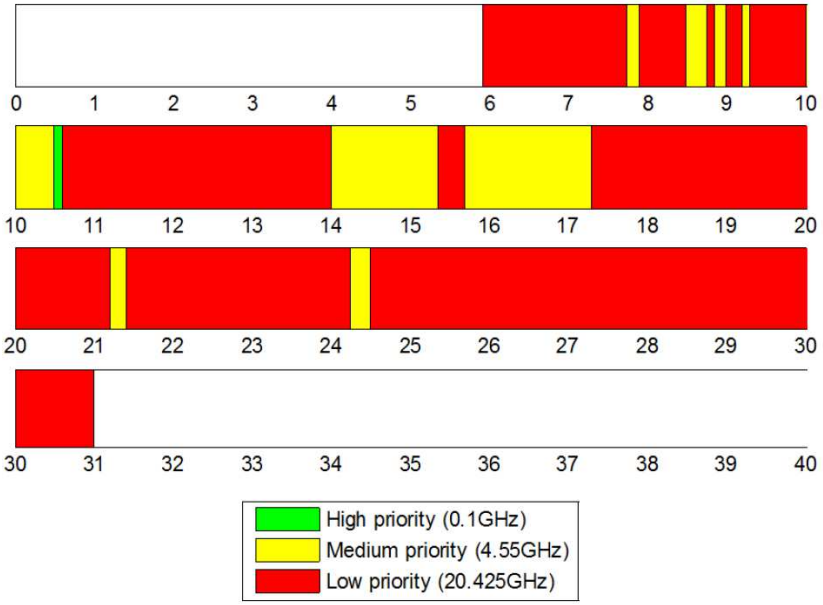


Figure 3: METIS results for co-existence between 6 GHz and 31 GHz

It is also to be noted that a key aspect of shareability of spectrum is the relative directivity of the antennas involved by the services sharing. Sharing between high-gain antennas like those used by satellite and point-to-point microwave has generally been shown to be feasible. However, once low-gain or uncontrolled-gain antennas are used, and multipath is used to boost channel capacity, interference cases multiply and sharing becomes problematic. An important aspect to the consideration of 5G at mmWave bands is whether the actively formed beams will have significant sidelobe suppression in addition to their designed-for main beam directivity. This aspect remains to be determined by the terminal developers.

Question 6:

a) Given the capacity and latency targets currently being discussed for 5G how do you anticipate backhaul will be provided to radio base stations? Are flexible solutions available where the spectrum can be shared between mobile access and wireless backhaul?

b) What, if any, spectrum will be required? What channel sizes will be needed? Will the bands used be similar to those currently used for wireless backhaul?

Fibre networks, microwave networks, as well as geostationary and non-geostationary satellite systems will all have a vital part to play to providing backhaul for future 5G systems. Traditional satellite networks can provide an efficient multicast distribution of popular content across the 5G network, thus relieving some of the backbone bandwidth requirements. This is especially relevant as video-centric content, in particular in high-definition (HD) and ultra-high definition (UHD) formats, will represent a large majority of the most appealing content. Existing and future high-throughput satellite systems (using satellite frequencies in C-

band, Ku-band, Ka-band, and beyond) will be able to provide high-capacity backhaul links anywhere, including in otherwise hard to reach or uneconomic areas.

Question 7: Should we expand the scope of bands being reviewed beyond the 6-100 GHz range?

ESOA believes that there are very extensive and very viable opportunities to accommodate 5G terrestrial radio systems in higher mmWave frequencies, rather than in the lower sub-mmWave bands between 6 GHz and 31.0 GHz because the latter bands are heavily used by other radio services.

A 'win-win' approach would be to identify bands for 5G terrestrial between 31 GHz and 100 GHz as it should enable a viable and sustainable growth outcome for all stakeholders including 5G / IMT and it would avoid a detrimental effect to current and future huge investments in satellite systems / space systems in bands below 31 GHz.

Given the above, there does not appear to be good reason to expand the scope of bands being reviewed by Ofcom for 5G beyond the 31 – 100 GHz range.

This is shown by the various comments made to the current ongoing FCC 'Spectrum Frontiers' NOI. There are already a considerable number of studies, identification and research projects that are taking place in higher mmWave frequencies.

Below is non-exhaustive list that captures the comments received by many of the respondents to the FCC NOI. It highlights the focus on frequency bands above 31 GHz. The bands identified above 31 GHz have been highlighted in red, indicating strong support from the 5G industry and other stakeholders for such bands.

Table 1: Table of Summary of FCC NOI for above 24 GHz

Company	General Opinion	Bands identified
SAMSUNG	• "In particular, the Commission should study how to enable licensed mobile broadband in the 28 GHz and 39 GHz LMDS as well as the 37/42 GHz bands for 5G." • "Secondary attention should also be paid to spectrum at 60 GHz"	"28 GHz"; "39 GHz"; "37 GHz"; / "42 GHz"; "60 GHz".
THE NATIONAL CABLE & TELECOMM ASSOCIATION	• "As the NOI notes, new research suggests that these bands can now be much more intensively used to help meet the growing demand for mobile services."	"42 GHz", "70/80 GHz"
FIBERTOWER LCC	• "Support studies above 24 GHz"	"24- 39 GHz"; "10-11 GHz";
CTIA	• "applaud the Commission for launching this proceeding to investigate the potential opportunities for using mmW bands to accelerate the deployment of novel 5G services. Spectrum below 3 GHz, however, will still be critical to providing consumers with adequate network coverage."	"spectrum above 24 GHz will not replace the need to identify spectrum below 3 GHz"
THE FIXED WIRELESS COMMUNICATIONS COALITION, INC.	• "The FWCC believes that significant utilization of above 24 GHz spectrum for Fixed Service wireless backhaul will be a necessary part of the infrastructure to support mobile services in the future"	"42-43.5 GHz"; "71-76 GHz"; "81-86 GHz"

ALCATEL-LUCENT	• "ALCATEL URGES THE COMMISSION TO CONSIDER THE IMPORTANCE OF FIXED WIRELESS SERVICES IN HIGH FREQUENCY BANDS EVEN AS TECHNOLOGY INNOVATIONS UNLOCK THESE BANDS FOR MOBILE USES." • "PROVIDING INDOOR COVERAGE FROM OUTDOOR CELLS MAY NOT BE FEASIBLE AT HIGH FREQUENCIES. IT IS THUS EXPECTED THAT SEPARATE HIGH FREQUENCY SMALL CELLS WILL BE DEPLOYED BOTH INDOORS AND OUTDOORS IN AREAS OF HIGH TRAFFIC DEMAND."	"Below 6 GHz; Above 20 GHz; (combined with 4G LTE and WLAN radio carriers)"
AMERICAN RADIO RELAY LEAGUE, INCORPORATED	• "THE COMMISSION SHOULD UTILIZE EXISTING MOBILE ALLOCATIONS IN THE MMW BANDS ABOVE 24 GHZ WHICH CAN BE INTERNATIONALLY HARMONIZED."	"77-81 GHz"; "24.00-24.05 GHz"; "Above 95 GHz".
NOKIA	• "NOKIA VIEWS THAT 5G WILL INDEED USE EXISTING AND NEW IMT SPECTRUM BELOW 6 GHZ AS WELL AS FROM 6-100 GHZ." • "WE RECOMMEND THAT THE COMMISSION TRIES TO MAKE LARGE BLOCKS OF CONTIGUOUS SPECTRUM (E.G., AT LEAST 400 MHZ) AVAILABLE TO THE EXTENT POSSIBLE."	"Below 6 GHz"; "28 GHz" and "72 GHz"; "60 GHz"; "57-64 GHz".
ERICSSON	• "24 GHZ BANDS COULD BE SUITABLE FOR BACKHAUL. BANDS ABOVE 30 GHZ ARE MORE CHALLENGING. ERRICSSON LEAD THE METIS PROJECT."	"<6 GHz and > 10 GHz"; "39 GHz"; "37-38.6 GHz"; "28.6-40 GHz"; "60 GHz"; "70 GHz and 80 GHz are attractive." "The 42-42.5 GHz unless it is combined with 42.5-43.5 GHz."
THE NATIONAL CABLE & TELECOMMUNICATIONS ASSOCIATION	• "THE COMMISSION SHOULD EXPLICITLY PROPOSE TO PERMIT UNLICENSED OPERATIONS IN FUTURE PROCEEDINGS CONCERNING INDIVIDUAL BANDS ABOVE 24 GHZ"	
4G AMERICAS	• "5G INCLUDES THE ENTIRE 5G ECOSYSTEM, SUCH AS AIR INTERFACES, DEVICES, TRANSPORT, ANTENNAS, AND PACKET CORE." • "THE COMMISSION SHOULD BE MINDFUL OF HOW ITS REGULATORY DECISIONS WILL IMPACT INVESTMENT DECISIONS ACROSS THE ECOSYSTEM, END-TO-END."	"1-6 GHz."
HUAWEI	• "AS A CORE MEMBER OF METIS, WHICH WAS LAUNCHED IN 2012 TO DEVELOP 5G SYSTEM CONCEPTS AND RELATED KEY TECHNOLOGY COMPONENTS, HUAWEI LEADS METIS RESEARCH ON THE WIRELESS AIR INTERFACE FOR 5G." • "THE MOST ADVANTAGEOUS MMW OPERATING BANDS MAY THUS BE THOSE WHERE BANDWIDTHS IN EXCESS OF 1 GHZ CAN BE ASSIGNED. TO MEET THE ADDITIONAL SPECTRUM REQUIREMENTS FOR 5G, HUAWEI STRONGLY BELIEVES THAT SPECTRUM ASSIGNMENTS, INCLUDING THOSE IN THE MMW BANDS, MUST BE HARMONIZED GLOBALLY."	"Above 24 GHz;" "60 GHz."
XO COMMUNICATIONS, LLC	• "THE COMMISSION TO PERMIT XO AND OTHER UPPER	"39 GHz."

	MICROWAVE BAND LICENSEES TO OPERATE 5G COMMERCIAL MOBILE FACILITIES UNDER THE EXISTING, EXCLUSIVE GEOGRAPHIC AREA LICENSING REGIME IN EACH FREQUENCY BAND."	
MOTOROLA	• "IT IS ESSENTIAL THAT THE COMMISSION WORK IN CONCERT WITH OTHER GOVERNMENTS AND INDUSTRY STAKEHOLDERS IN EXPLORING SPECTRUM AND TECHNICAL REQUIREMENTS FOR NEXT GENERATION MOBILE SYSTEMS."	"60 GHz"; "45 GHz"; "27.5-28.35 GHz"; "39 GHz"; "37/42 GHz"; "70/80 GHz"; "73 GHz".
WI-FI ALLIANCE	• "WI-FI ALLIANCE THEREFORE ENCOURAGES THE FCC TO CONSIDER AUTHORIZING MOBILE AND FIXED OPERATIONS PURSUANT TO ITS PART 15 RULES WHEN ASSESSING THE FUTURE USE OF THE SPECTRUM BANDS ABOVE 24 GHZ"	"57-64 GHz"; "64-71 GHz"; "Above 71 GHz".
VERIZON	• "IT IS IMPORTANT TO AVOID PREMATURE ASSUMPTIONS ABOUT ABOVE-24 GHZ TECHNOLOGY"	
T-MOBILE	• "TO EXPLOIT THE FULL POTENTIAL OF THIS SPECTRUM, THE COMMISSION SHOULD RELY PREDOMINANTLY ON EXCLUSIVE USE LICENSES." • "LICENSEES WILL THEREFORE BE INCENTIVIZED TO OBTAIN LICENSES WITH A LARGE AMOUNT OF BANDWIDTH (BETWEEN 500 MHZ AND 1 GHZ)."	"Below 3.6 GHz; 60 GHz."
STRAIGHT PATH'S	• "THE COMMISSION SHOULD REFRAIN FROM GRANTING ANY NEW APPLICATIONS FOR SATELLITE OPERATIONS IN THE V-BAND PENDING THE OUTCOME OF THE 5G NOI PROCEEDING."	"39 GHz."
MOBILE FUTURE	• "THE ABOVE 24 GHZ NOI IS A POSITIVE STEP TOWARD EMPLOYING NEW TECHNOLOGICAL ADVANCES THAT CAN HELP PROVIDE SERVICES TO CONSUMERS." • "IN SHORT, THE ABOVE 24 GHZ BANDS ARE NOT A CURE ALL FOR THE SPECTRUM CRUNCH."	"Below 6GHz."
TELECOMMUNICATIONS INDUSTRY ASSOCIATION	• "THERE IS A SIGNIFICANT AMOUNT OF SPECTRUM POTENTIALLY AVAILABLE FOR MOBILE BROADBAND IN BANDS AT 24 GHZ OR ABOVE."	"28 GHz"; "38-39 GHz"; "60 GHz"; "72 GHz"; "70 and 80 GHz".
QUALCOMM	• "SUPPORT OF BANDS ABOVE 24 GHZ WILL REQUIRE ADDITIONAL RESEARCH AND DEVELOPMENT, WHICH QUALCOMM AND MANY OTHERS IN THE INDUSTRY ARE BUSILY WORKING ON."	"39 GHz"; "37/42 GHz"; "64 to 71 GHz"; "< 5GHz."
VIVINT WIRELESS,	• "THE COMMISSION MUST PROTECT EXISTING FIXED SERVICE OPERATIONS FROM HARMFUL INTERFERENCE AND SHOULD ESTABLISH PRIORITY RIGHTS FOR FIXED SERVICES."	"27.5-28.35 GHz"; "29.1-29.25 GHz"; "31-31.3 GHz"; "38.6-40 GHz"; "37.0-38.6 GHz"; "42.0-42.5 GHz"; "57-64 GHz"; "64-71 GHz"; "71-76 GHz"
IEEE	• "IEEE 802 SUPPORTS THE COMMISSION'S CONCEPT OF EXTENDING THE EXISTING PART 15 UNLICENSED RULES TO INCREASE THE 60 GHZ BAND FROM THE PRESENT 57 TO 64 GHZ TO 57 TO 71 GHZ"	"57 to 71 GHz."

CONSUMER ELECTRONICS ASSOCIATION	• "THE MMW BANDS AT 24 GHZ, 28 GHZ, 39 GHZ AND 70-80-90 GHZ ARE BEING USED TO PROVIDE IMPORTANT BACKHAUL, SATELLITE, AND OTHER POINT-TO-MULTIPOINT SERVICES THAT SHOULD NOT BE FORECLOSED UNDER NEW RULES."	"5.8 GHz;" "30-40 GHz and 60 GHz."
THE WIRELESS INNOVATION FORUM	• "THE COMMISSION TO MAKE TECHNOLOGY AND APPLICATION NEUTRALITY A KEY ASPECT OF THE RULES ULTIMATELY ADOPTED IN AN ABOVE 24 GHZ PROCEEDING."	"> 86 GHz"; "> 95 GHz".
NYU WIRELESS	• "RECOMMEND THE ALLOCATION OF 10 GHZ OF UNLICENSED SPECTRUM (5 GHZ BELOW 100 GHZ, AND 5 GHZ ABOVE 100 GHZ)."	"Above 42.5 GHz"; "60 GHz."
INTERDIGITAL,	• "INTERDIGITAL IS MOTIVATED BY ITS COMMITMENT TO WIRELESS INNOVATION AND BELIEVES IN THE STRONG POTENTIAL OF MMW TECHNOLOGY IN CONJUNCTION WITH SMALL-CELL DEPLOYMENTS TO MEET THE UNPRECEDENTED SPECTRUM DEMAND."	"60 GHz"; "64-71 GHz".
UNIVERSITY OF WISCONSIN		"80 GHz."
BLUWAN'S	• "BLUWAN BELIEVES THAT 42GHZ AND ITS LIMITED RANGE AND HIGH BANDWIDTH (AND RE-USE FACTOR) IS PERFECTLY POSITIONED TO MEET THE CHALLENGES OF 5G HETEROGENEOUS NETWORK DEPLOYMENTS, SPECIFICALLY FOR THE BACKHAUL OF THESE HETNETS."	"42GHz."

Question 8: Do you agree that it is likely to be necessary for bands to have an existing allocation to the mobile service? Does this need to be a primary allocation?

ESOA considers that if a specific identification is to be made at ITU / WRC level or European (CEPT / EU) level to 5G terrestrial radio systems, it should be in relevant bands above 31 GHz. Approximately 66 % of the frequency range between 31 GHz and 100 GHz are already allocated to the mobile service by the ITU; hence there should be ample opportunities to achieve such identification at ITU WRC-2019 or WRC-2021 for 5G / IMT in existing mobile services bands above 31 GHz. Again, ESOA advises Ofcom consider the approach of identify bands for 5G terrestrial between 31 GHz and 100 GHz.

Given the above, ESOA does not see a need for consideration of new mobile service allocations at ITU level or UK / European level for accommodation of future 5G radio systems.

However the existence of an allocation to the mobile service does not itself give an indication that a band is suitable as a potential band for 5G. The allocations to the mobile service in these frequency bands were made many years ago, before the possible use of mobile broadband systems operating at such frequencies could possibly have been envisaged.

Question 9: Do you agree with the criteria we have used for our initial filter of bands, and are there other criteria that could also be used?

ESOA agrees that there are benefits in Ofcom adopting some basic criteria to initially filter the frequency bands that could be considered. ESOA believe relevant factors such as "international harmonisation" and "availability of sufficient contiguous bandwidth" are important.

ESOA also consider that criteria which take into account the extent of investments in establishing and operating space or terrestrial radio systems in a given band must also be taken into proper account. ESOA

does not support selecting bands where companies have already deployed significant investments to deploy other terrestrial or space services, since the introduction of 5G in those bands such as C-band, X-band, Ku-band, Ka-band. For example, noting the suggestion of some 5G proponents (e.g. Samsung) for 5G spectrum identification at 28 GHz, Ofcom should recognise that satellite operators have invested over US $10 billion in Ku-Band and Ka-band satellite systems for providing TV and broadband services in both the UK and in other countries around the world.

ESOA sees some limitations with current Ofcom criteria for initial filtering of spectrum, as you can see from our response to Question 11.

Question 10: Of the spectrum bands/ranges mentioned in this section, are there any that should be prioritised for further investigation?

It is not just the satellite industry which supports focussing the search for 5G bands above 31 GHz. The following table summarises what the industry leaders and main advocates who are already doing extensive research, trials and testing on 5G have identified as suitable bands for 5G / IMT above 31 GHz.

Company	General Opinion	Bands identified
SAMSUNG	• "In particular, the Commission should study how to enable licensed mobile broadband in ….39 GHz LMDS as well as the 37/42 GHz bands for 5G." • "Secondary attention should also be paid to spectrum at 60 GHz"	"39 GHz"; "37 GHz"; / "42 GHz"; "60 GHz".
THE NATIONAL CABLE & TELECOMM ASSOCIATION	• "New research suggests that these bands can now be much more intensively used to help meet the growing demand for mobile services."	"42 GHz", "70/80 GHz"
THE FIXED WIRELESS COMMUNICATIONS COALITION, INC.	• "The FWCC believes that significant utilization of above 24 GHz spectrum for Fixed Service wireless backhaul will be a necessary part of the infrastructure to support mobile services in the future"	"42-43.5 GHz"; "71-76 GHz"; "81-86 GHz"
AMERICAN RADIO RELAY LEAGUE, INCORPORATED	• "The Commission Should Utilize Existing Mobile Allocations in the mmW Bands Above 24 GHz Which Can be Internationally Harmonized."	"77-81 GHz; "Above 95 GHz".
NOKIA	• "We recommend that the Commission tries to make large blocks of contiguous spectrum (e.g., at least 400 MHz) available to the extent possible."	"72 GHz"; "60 GHz"; "57-64 GHz".
ERICSSON		"39 GHz"; "37-38.6 GHz"; "28.6-40 GHz"; "60 GHz"; "70 GHz and 80 GHz are attractive." "The 42-42.5 GHz unless it is combined with 42.5-43.5 GHz."
HUAWEI	• "The most advantageous mmW operating bands may thus be those where bandwidths in excess of 1 GHz can be assigned. To meet the additional spectrum requirements for 5G, Huawei strongly believes that spectrum assignments, including	"60 GHz."

	THOSE IN THE MMW BANDS, MUST BE HARMONIZED GLOBALLY."	
XO COMMUNICATIONS, LLC	• "THE COMMISSION TO PERMIT XO AND OTHER UPPER MICROWAVE BAND LICENSEES TO OPERATE 5G COMMERCIAL MOBILE FACILITIES UNDER THE EXISTING, EXCLUSIVE GEOGRAPHIC AREA LICENSING REGIME IN EACH FREQUENCY BAND."	"39 GHz."
MOTOROLA	• "IT IS ESSENTIAL THAT THE COMMISSION WORK IN CONCERT WITH OTHER GOVERNMENTS AND INDUSTRY STAKEHOLDERS IN EXPLORING SPECTRUM AND TECHNICAL REQUIREMENTS FOR NEXT GENERATION MOBILE SYSTEMS."	"60 GHz"; "45 GHz"; "39 GHz"; "37/42 GHz"; "70/80 GHz"; "73 GHz".
T-MOBILE	• "TO EXPLOIT THE FULL POTENTIAL OF THIS SPECTRUM, THE COMMISSION SHOULD RELY PREDOMINANTLY ON EXCLUSIVE USE LICENSES." • "LICENSEES WILL THEREFORE BE INCENTIVIZED TO OBTAIN LICENSES WITH A LARGE AMOUNT OF BANDWIDTH (BETWEEN 500 MHZ AND 1 GHZ)."	"60 GHz."
STRAIGHT PATH'S	• "THE COMMISSION SHOULD REFRAIN FROM GRANTING ANY NEW APPLICATIONS FOR SATELLITE OPERATIONS IN THE V-BAND PENDING THE OUTCOME OF THE 5G NOI PROCEEDING."	"39 GHz."
TELECOMMUNICATIONS INDUSTRY ASSOCIATION	• "THERE IS A SIGNIFICANT AMOUNT OF SPECTRUM POTENTIALLY AVAILABLE FOR MOBILE BROADBAND IN BANDS AT 24 GHZ OR ABOVE."	"38-39 GHz"; "60 GHz"; "72 GHz"; "70 and 80 GHz".
QUALCOMM	• "SUPPORT OF BANDS ABOVE 24 GHZ WILL REQUIRE ADDITIONAL RESEARCH AND DEVELOPMENT, WHICH QUALCOMM AND MANY OTHERS IN THE INDUSTRY ARE BUSILY WORKING ON."	"39 GHz"; "37/42 GHz"; "64 to 71 GHz";

Question 11: Are there any bands/ranges not mentioned in this section that should be prioritised for further investigation? If so, please provide details, including why they are of particular interest.

Based on industry's responses, the frequency bands mentioned as a likely block of free spectrum (not used extensively by FSS/MSS Services) above 31 GHz to be considered for identification for 5G include a 500MHz – 1GHz contiguous range for 5G between 37 – 39 GHz and an additional 500 MHz – 1 GHz of spectrum within the range 43.5 – 47 GHz. Further studies should be done in this regard.

The mmWave frequencies from 31 GHz to 86 GHz, e.g. at 57 - 64 GHz and 70 - 80 GHz, would be particularly suitable for access, front-hauling and backhauling, as well as for short range links. More opportunities are expected to exist in higher mmWave bands above 31 GHz than in sub-mmWave bands below 31 GHz. This is due to the following factors:

- Lower intensity of use by radio systems in bands above 31 GHz than in frequency bands below 31 GHz
- Increased isolation between co-existing terrestrial radio systems that follows from the propagation properties in higher bands.

Questions 12: Are there any particular bands/ranges that would not be suitable for use by future mobile services? If so, please provide details.

ESOA strongly encourages Ofcom to look at accommodation of 5G/IMT terrestrial services in higher mmWave frequencies in relevant frequency bands above 31.0 GHz, where possible in frequency bands not allocated on a primary or co-primary basis by the ITU to satellite or space services, recognizing that the extent of current terrestrial radio system and satellite system spectrum use is much less intense above 31 GHz.

ESOA encourages Ofcom to identify relevant frequency bands for 5G above 31 GHz on the above basis, since that would enable the timely and sustainable growth of future 5G terrestrial eco-system above 31 GHz and the continued and sustainable growth of satellite systems / space in bands below 31 GHz, without creating near term, medium term or longer term highly disruptive spectrum conflicts between future 5G radio systems and current and future innovative space services.

ESOA notes that some of the bands identified by Ofcom in section 3.9 of the CFI are allocated to and heavily used by satellite services. For one of the bands in question, 5925 – 8500 MHz, the ITU-R has recently completed relevant studies on the possible use by IMT systems ("draft new Report ITU-R [FSS-IMT C-BAND UPLINK]"[17]. This has found that use of these bands by IMT systems is not possible in the band 5850 – 6425 MHz. Although the band 6425 – 7075 MHz was not studied, the same characteristics of FSS systems apply, and the same conclusions would apply. Hence the band 5925 – 7075 MHz can already be ruled out on the basis of recent existing technical studies.

Other bands proposed by Ofcom which are heavily used by satellite services are 10.7 – 11.7 GHz, 14.4 – 14.8 GHz, 17.8 – 19.7 GHz and 27.5 – 29.5 GHz. Although we recognise that Ofcom has not used the feasibility of sharing with existing services as a criterion in deriving this list, to put forward these bands and potential bands for 5G does not seem credible. A very simple examination of the satellite services currently in operation and currently being deployed will indicate that these bands are not feasible for terrestrial 5G systems.

Question 13: What additional information, beyond that given in Annex 5 would be useful to allow stakeholders to develop their own thinking around spectrum options?

No comment.

Question 14: What are the most important criteria for prioritising bands going forward?

ESOA specifically calls out the following criteria for prioritising bands for 5G/IMT going forward:

- Ensuring existing and planned radio services already deployed or planned to be deployed under existing ITU radio allocations are:
  - not subject to unacceptable interference from future 5G / IMT systems;
  - not subject to constraints in their future development by future 5G / IMT systems;
  - not subject to the threat of future displacement out of their current operating bands due to progressive encroachment / entry by 5G / IMT radio systems.
- Ensuring existing, planned and future investments targeting the UK by satellite companies are not prejudiced or put at risk;
- Targeting the greatest opportunity for global harmonisation at ITU level;
- Ability to deploy as soon as possible and with the minimum amount of disturbance of existing users and uses;
- Using an existing already primary allocation to the Mobile Service;

[17] ITU-R document 5/123

- Targeting large contiguous allocation of spectrum for terrestrial 5G / IMT of multiple GHz in order to accommodate up to 1 GHz per operator multiple operators
- Higher carrier frequency in order to increase overall system capacity through efficient frequency reuse