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

Ofcom should note that this review will probably not capture the level of response from commercial organisations involved in exploitation of space enabled services in the "Space Science" category which Ofcom would have hoped for. This is because the use space data is becoming so ubiquitous that many of these commercial organisations do not realise the technical aspects of how the satellite or the sensors utilise RF spectrum - especially in the fields of Earth Observation and Geo Information and hence would neither be aware of the Ofcom consultation nor be able to answer many of the questions. Some factorisation of this should be taken into account.

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)?:

This sector has not included the commercial Earth Observation / Geo Information sector and its applications. A 2013 report by EARSC gave the following European market size evaluation "Over the period 2006 to 2012, revenues for the sector have increased at a compound annual growth rate (CAGR) of 10.7% from an estimated €412m in 2006 to €757m in 2012." It is assumed that these activities together with meteorological services are included in Ofcom's "Space Science Sector" under the heading "Earth Exploration Satellite Service".

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?:

Our submission is given in Q15-24

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.:

Our submission is given in Q15-24

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.:

Our submission is given in Q15-24

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).:

Our submission is given in Q15-24

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

Our submission is given in Q15-24

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).:

Our submission is given in Q15-24

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.:

Our submission is given in Q15-24

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?:

Our submission is given in Q15-24

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?:

Our submission is given in Q15-24

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.:

Our submission is given in Q15-24

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)?:

The classification has missed the fact that Met satellite sensing now includes active sensors - for example radio altimeters, active radiometers, in-orbit rain precipitation radar. Hence a "Metsat" ITU classification needs to be added to the "Active Sensing" group.

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?:

In respect of Earth Observation / Geo-Information services the following data has been extracted from the latest (2013) report "A Survey into the State and Health of the European EO Services Industry" prepared by EARSC under assignment from ESA, September 2013:

The value chain which EARSC determined for this market sector is:

IMPOSSIBLE TO UPLINK DIAGRAM

Again quoting from the same report, revenues are split:
EO service companies in Europe are active right across the value chain (illustrated) and the chart below shows the relative size of each part of the value chain. The first three segments are dealing with satellite data either from their own (or licensed) satellites, from third party missions or as an operator of a receiving station taking data from satellites under contract or license. Data selling activities represent 40% of the market by value. Satellite data is then processed into geoinformation, often in combination with other
data eg. in-situ measurements, through value-adding services. We have chosen to recognise two parts to this downstream segment: VA companies dealing directly with the satellite data and Geographic Information (GI) services companies which are dealing with spatial data and using products which have been generated using satellite data. Perhaps the clearest example here is the use of GoogleEarth but there are many others. The "information" segment comprises 43% of the market. The remaining 17% is made of companies which are selling software.

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.:

We cover several roles in the EO service chain:
Data reseller (for SAR products);
Partial ground station operator (for UK data reception and user terminals for Cosmo-Skymed satellite constellation) in co-operation with RALSpace and Satellite Applications Catapult;
Consultancy and Value-Adding services - (for both commercial services and the scientific earth observation satellites of ESA);
Software developments - (for both commercial services and the scientific earth observation satellites of ESA);

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.:

It is difficult to link specific applications to specifics in terms of either active or passive sensor frequencies and their satellite uplink/downlink comms frequencies. The EO services industry just doesn't think in that way. At the most it recognises the sensor frequencies but relies on the satellite owner to cope with the uplink and downlink comms frequencies. As a result most players in this market sector are unaware of the comms frequencies and Ofcom would be advised to consult globally with satellite owners - including ESA, Eumetsat and EU, NOAA and the dual use owners of systems such as Pleides (France), Cosmo-Skymed (Italy), Terrasar-X and others (Germany).

We are aware of 4 specific items as follows:

In terms of the Copernicus programme, the first satellite, Sentinel-1 launched in April 2014 carries a C-band Synthetic Aperture Radar at 5.4GHz. Sentinel 3, due for launch in 2015 carries a dual frequency Ku/C-Band active altimeter, together with a passive dual frequency and highly sensitive 23.8/36.5 GHz radiometer (radiometric accuracy of 3K absolute, 0.6 K relative).

The UK has also obtained both research and commercial access to the Cosmo-Skymed X-Band synthetic aperture radar system. This 4 satellite constellation has the highest revisit frequency and greatest ground resolution available. It requires the sensor freq of 9.6GHz with bandwidth of +/- 400MHz. It has downlink capability to the UK ground station at Chilbolton at 8-8.5 GHz. UK Gov is planning a research call and Uk industry is relying on access to the system to enable growth in high resolution downstream applications, such as infrastructure monitoring, flood response planning, agritech etc.

The ESA Soil Mositure and Ocean Salinity (SMOS) satellite whilst a scientific research satellite shows promise for future development into an operational system. This uses an L-Band radiometer at 1.4GHz. Future operational use is predicated on feedback from the agricultural community and the food security supply chain for whom knowledge of soil moisture would provide significant advantage in crop planning and yield estimation.

Many new multiple satellite "cubesat" commercial constellations are being planned and already being launched. These are primarily US driven but will soon include European and potentially UK companies. These satellites may be downlinking in VHF or S-band. Their market potential to drive EO services is huge - especially with direct downlink to maximise on revisit time.

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).:

We provide Earth Observation applications and services in areas such as :

- Earth science research
o Providing industrial services on the quality of earth observation data to enable the science community to better determine the responses of the earth's atmosphere, oceans and land to current stresses.
- Climate understanding and environmental protection
o Providing software systems to assist in operationalising climate data for benefit of EU citizens and scientists
- Public protection and disaster relief
o Eg providing flood response maps in times of UK emergencies such as recent 2013 Somerset and Thames valley flooding
- Defence and security
- Energy - oil & gas and alternative energy eg wind farms
o Eg SAR derived products for monitoring deployed assets, and planning new installations
- Productivity and efficiency improvements in agriculture
o Eg crop monitoring using SAR and extension to food security.
- Civil infrastructure planning and monitoring - e.g. rail and tunnel subsistence
o Eg interferometry applications for large rail infrastructure planning, tunnel excavations, water leakage, and electricity distribution.

Many other companies cover other user sectors or the same sectors with different offerings. The best insight into the market size and impact is give in the latest (2013) report "A Survey into the State and Health of the European EO Services Industry" prepared by EARSC under assignment from ESA, September 2013:

Unsurprisingly, the largest number of companies can be found in countries which have a history of investment in space activities; France, Germany, UK and Italy. The largest number in 2012 are to be found in the UK (a trend which starts between 2003 and 2006) whereas in 2003 France and Germany were found to be dominant. Strong growth has also taken place in Spain, Netherlands, Belgium and Austria. Today, we also find that there are companies spread throughout Europe with at least one company in almost every country. [Note that EARSC found over 50 UK companies involved in EO value chain in 2013].
Over the period 2006 to 2012, revenues for the sector have increased at a compound annual growth rate (CAGR) of 10.7% from an estimated €412m in 2006 to €757m in 2012.
The chart shows this increase which is calculated from the actual reported revenues (€568m) coming from the 133 companies reporting plus an estimated €189m for the additional 186 companies. The reported revenues represent 75% of the total calculated figures.

IMPOSSIBLE TO UPLOAD DIAGRAM

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

The UK government has identified through the "Innovation & Growth Strategy" that UK Space industry should be targeting a large growth especially in the downstream services sector - to achieve market growth to £40 billion by 2030, ie to increase its share of the global market from the current 7.7 % to 10%. The downstream market takes up the majority of this market growth. Current market results are showing good growth. The UK captures 6.3% to

7.7% of the global space economy turnover growing on average 8.8% per annum since 1999/00 and 8.6% since 2008/09 to reach a turnover of £11.85 billion in 2012/13. The UK space economy directly contributed £5.1 billion to UK GDP in 2012/13, exhibiting a high value-added share of 43.4% of turnover.

Specifically the EO services market will be affected by 3 major trends which will drive expansion - greater use of the data with more economic benefit but also requiring probably more use of spectrum.
- The operational Copernicus satellite system - expanding from 2 satellites today (Sentinel-1A and Sentinel-2A) to >6 within the next few years - S-1A, S-1B, S-2A, S-2B, S-3A, S-3B, S5. The free data and guaranteed long term availability of the data will drive new applications and confidence in the user markets. Provided the spectrum is not removed.
- The increasing trend to launch constellations of cubesats to monitor the earth. These are low cost and have excellent revisit times provided local downlink is available.
- Increasing use of SAR imaging driven by the unique ability of SAR active sensors to see through cloud and hence take data in all circumstances in mid latitude regions such as the UK.

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).:

It is very difficult to answer this question in a "per application" manner. There are no specific drivers which are linked to one application alone. There are many examples all of which would be similar.

One case would be the monitoring of ground movement using SAR. This is a new but fast growing area. Looking at a UK context this is important in such diverse user areas as: current National Rail infrastructure, new railway infrastructure planning and monitoring such as HS2, tunnelling such as in London, monitoring of critical national infrastructure such as gas terminals, nuclear facilities etc.

This reflects a growing demand for very high resolution pictures produced by synthetic aperture radars (SAR) operating in the Earth exploration-satellite service (EESS) (active).

This image resolution needed for environmental monitoring can only be achieved by correspondingly downlink comms transmission bandwidth. Of course there would be additional sensing observations taken but these would drive the need for minimising interference in the specific allocated SAR bands rather than driving the need for a large number of sensor frequencies.
The response of a SAR depends on the allocated sensing frequency. A small number of freqencies should be "reserved" across X, C and S band.

Finally in respect of the overall Eo services market the (2013) report "A Survey into the State and Health of the European EO Services Industry" prepared by EARSC under assignment from ESA, September 2013, indicated that the following areas were driving the market growth:

IMPOSSIBLE TO UPLOAD DIAGRAM which showed main markets driving growth are: Security, Planning, Oil&Gas, environment & Climate, Agriculture, Emergency, Maritime, Forestry.

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.:

Again it is difficult to make the link across from market trend to a specific band. As a EO services company we don't know the bands used by the satellites for uplink/downlink. We simply know that the data needs to be taken and downlinked. We would be highly concerned about market growth if the access to data is restricted and we be concerned about market crash if the Operationalisation and long-term data guarantees of the Copernicus programme were threatened.
On a sensor perspective and taking a commercial view, the protection of SAR frequencies in S, C and X band is most important -for both Copernicus and commercial systems such as Cosmo-Skymed.

On a scientific basis we note also the future P-band (<1GHZ) Biomass mission which is being built by ESA. This has a lot of UK scientific input and will be of major importance in monitoring climate change - through measuring radar returns from forests (primarily those in tropics under cloud).

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?:

SKA makes no difference to EO services.

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?:

We do not have the knowledge to comment on filtering and data processing opportunities.

Time based sharing of frequency seems fraught with problems and in our opinion is not workable.

Geographic based sharing of frequency - especially for uplink/downlink is feasible, but due note should be taken of recent trends in mobile reception and in the potential multiple reception stations for new commercial cubesat constellations. Perhaps software defined radio techniques could enable one downlink to use multiple frequencies at different global locations?

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?:

We have no expertise to know whether this is feasible but perhaps software defined radio techniques could enable one downlink to use different frequencies at different global locations?

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.:

Not aware of any.