Ofcom

Strategic review of satellite and space science use of spectrum

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

No.

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 radiocommunication service(s)?

Yes. The list of relevant ITU services in section 3.8 is incomplete. The EESS and MetSat as defined in 1.51 and 1.52 of the Radio Regulations is missing which provides the services definition for the communication part under the EESS and MetSat services. Bullet 1 on EESS gives a description of applications under the EESS (active) and EESS (passive) and should therefore clearly defined us such. When talking about EESS in general as it is done in bullet 1, the communication part between the satellite and the ground stations should be described.

Likewise in Table 2: MetSat should not appear under passive allocation. It should rather appear twice under active applications:

1) MetSat should be added to the last row “space science data communications”

2) and in additional row as “dissemination of information related to the weather and environment”.

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?

No comments on the value chain. The revenues are broken down among the equipment manufacturers, launch providers and Earth station operators the other half, namely the satellite operators, the service, content & application providers and most of the users don’t make revenue, as they are usually public services funded by the governments, such as EUMETSAT, the MetOffice, the ECMWF, defence, universities.

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.

EUMETSAT is a "non profit" satellite operator funded by its 30 member states with the task to operate the European meteorological satellites for its member states and provide them with the data acquired by the instruments operated on these satellites.

We <u>use</u> the following applications in the framework of the Space Operation (SO), EESS, MetSat, EESS (active), EESS (passive) services, but also in the framework of the FSS, RNSS, MSS services:

- Telemetry, Telecommand and Ranging of the spacecraft (SO);
- Transmissions of observation data to main reception stations (MetSat, EESS);
- Re-transmissions of pre-processed data through GSO MetSat satellites to meteorological user stations (EESS);
- Direct transmissions of un-processed observation data from NGSO MetSat satellites to meteorological user stations (MetSat, EESS);
- Alternative data dissemination of pre-processed data to users (not in MetSat or EESS bands, but in C- and Ku-Band) (FSS);
- Relay of signals from Data Collection Platforms and Search and Rescue transmitters (MSS);
- Active and passive microwave sensors <u>only on NGSO MetSats</u> (EESS (active), EESS (passive);
- Orbit determination and radio occultation systems using GPS, etc (RNSS).

One should also note that, as an indirect use of spectrum, EUMETSAT is also using and disseminating the data and measurements performed by meteorological and EESS satellites operated by other space agencies (NOAA, NASA, JAXA, CSA, CMA, …) and national meteorological agencies.

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;

<u>Answer:</u> See tables below.

- 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);

Answer: All passive measurements use the specific frequency bands allocated to EESS (passive) due to fundamental characteristics of the phenomena being measured. For EESS (active) the two bands used are essential to perform the measurements.

- whether the applications use continuous or intermittent measurements;

Answer: All measurements are continuous as a global set of data is required.

- the typical resolution and associated measurement bandwidths, including an indication of any implication for spectrum requirements;

Answer: See corresponding ITU-R Recommendations and Reports.

- the geography this use extends over (e.g. land or sea, and regional or global);

Answer: All measurements are global.

- the location of the gateway station(s) for TT&C and downlinking data;

Answer: There are currently no TT&C or gateway stations located in the UK. The type of Earth stations is currently limited to user stations to receive the measurement data .

- the estimated number of users.

The following table provides an overview of the MetSat and EESS allocated frequency bands used for communication to/from EUMETSAT satellites:

Application	Orbit	Frequency
Telemetry/Telecommand and Ranging	GSO/NGSO GSO/NGSO	2025 – 2110 MHz 2200 – 2290 MHz
Instrument raw data downlink	GSO NGSO GSO/NGSO GSO/NGSO	1675 – 1710 MHz 7750 – 7900 MHz 8025 – 8400 MHz 25.5 – 27 GHz
Low rate direct dissemination to user stations	GSO	1675 – 1710 MHz
High rate direct dissemination to user stations	GSO/NGSO NGSO	1675 – 1710 MHz 7750 – 7900 MHz
Data dissemination (EUMETCast) via commercial GSO satellites	GSO	3700 - 4200 MHz 10.7 - 12.5 MHz
Data Collection Systems	GSO/NGSO NGSO	401 – 403 MHz 460 – 470 MHz
Search and Rescue	GSO/NGSO GSO/NGSO	406 – 406.1 MHz 1544 – 1545 MHz

The following tables provide an overview of the frequency use of the passive microwave sounding instrument on the current NGSO MetSat satellites “Metop” (left) and on the second generation “Metop-SG” (right):

Instrument	**Centre Frequency**	**Bandwidth**	**Comments**
AMSU-A1/A2 (Metop & NOAA)	23.8 GHz 31.4 GHz 50.3 GHz 52.8 GHz 53.596 ± 0.115 GHz 54.40 GHz 54.94 GHz 55.50 GHz 57.290344 GHz + sub 89 GHz (15 channels)	270 MHz 180 MHz 180 MHz 400 MHz 170 MHz 400 MHz 400 MHz 330 MHz 375 MHz 6000 MHz (2.1/1.1 kbps)	Advanced Microwave Sounding Unit-A (AMSU-A) Temperature of the global atmosphere in all weather conditions
MHS (Metop) similar to AMSU-B (NOAA)	89 GHz 157 GHz 183.311 ± 1 GHz 183.311 ± 3 GHz 190.311 GHz (5 channels)	2.8 GHz 2.8 GHz 0.5 GHz 1 GHz 1.1 GHz (3.9 kbps)	Microwave Humidity Sounder (MHS) Humidity of the global atmosphere

Instrument	**Centre Frequency**	**Bandwidth**	**Comments**
Microwave Sounding Mission (MWS) Metop-SG-A	23.8 GHz 31.4 GHz 50.3 GHz 52.8 GHz 53.246+/-0.08 GHz 53.596+/-0.115 GHz 53.948+/-0.081 GHz 54.40 GHz 54.94 GHz 55.50 GHz 57.290344+/-0.217 89 GHz 164 – 167 GHz 183.311+/-7.0 GHz 183.311+/-4.5 GHz 183.311+/-3.0 GHz 183.311+/-1.8 GHz 183.311+/-1.0 GHz 229 GHz	270 MHz 180 MHz 180 MHz 400 MHz 2x140 MHz 2x170 MHz 2x142 MHz 400 MHz 400 MHz 330 MHz 2x78 MHz 4x36,4x16,4x8,4x3 4000 MHz 3000 MHz 2x2000 MHz 2x2000 MHz 2x1000 MHz 2x1000 MHz 2x500 2000 MHz	MWS allows for all-weather soundings over a wide swath in the spectral region between 23.8 and 229 GHz, with a footprint size of 17 - 40 km at nadir, depending on the channel. (Metop predecessor: AMSU-A/MHS)

The following table provides an overview of the frequency use of the "additional" passive microwave sensing instruments on next generation NGSO MetSat satellites "Metop-SG":

Instrument	Centre Frequency	Bandwidth	Comments
Microwave Imaging Mission (MWI) Metop-SG-B	18.7 GHz 23.8 GHz 31.4 GHz 50.3 GHz 52.61 GHz 53.24 GHz 53.75 GHz 89 GHz 118.7503+/-3.2 GHz 118.7503+/-2.1 GHz 118.7503+/-1.4 GHz 118.7503+/-1.2 GHz 165.5+/-0.725 GHz 183.31 +/- 7.0 GHz 183.31 +/- 6.1 GHz 183.31 +/- 4.9 GHz 183.31 +/- 3.4 GHz 183.31 +/- 2.0 GHz	200 MHz 400 MHz 200/1000MHz 400 MHz 400 MHz 400 MHz 400 MHz 4000 MHz 2x500 MHz 2x400 MHz 2x400 MHz 2x400 MHz 2x1350 MHz 2x2000 MHz 2x1500 MHz 2x1500 MHz 2x1500 MHz 2x1500 MHz	The Microwave Imaging Mission (MWI), providing precipitation and cloud imaging in the spectral range from 18.7 to 183 GHz with footprint sizes between 10 km and 50 km depending on the frequency. (Metop predecessor: ---)

Instrument	Centre Frequency	Bandwidth	Comments
Ice Cloud Imaging Mission (ICI) Metop-SG-B	183.31 +/- 7.0 GHz 183.31 +/- 3.4 GHz 183.31 +/- 2 GHz 243.2 +/- 2.5 GHz 325.15 +/- 9.5 GHz 325.15 +/- 3.5 GHz 325.15 +/- 1.5 GHz 448 +/- 7.2 GHz 448 +/- 3.0 GHz 448 +/- 1.4 GHz 664+/- 4.2 GHz	2x2000 MHz 2x1500 MHz 2x1500 MHz 2x3000 MHz 2x3000 MHz 2x2400 MHz 2x1600 MHz 2x3000 MHz 2x2000 MHz 2x1200 MHz 2x5000 MHz	The Ice Cloud Imaging Mission (ICI), providing ice-cloud and water-vapour imaging in the spectral range from 183 to 664 GHz, with a footprint size of 15 km. (Metop predecessor: ---)

The following tables provide an overview of the frequency use of the passive microwave sounding instrument on the current NGSO (66° inclination) EESS/MetSat satellites "Jason-2/-3" and future "Jason-CS/Sentinel-6" (left) and the soon to be launched NGSO (polar) EESS satellites "Sentinel-3" (right):

Instrument	**Centre Frequency**	**Bandwidth**
AMR (Jason-2 & -3) AMR-C (Jason-CS / Sentinel-6)	18.7 GHz 23.8 GHz 34 GHz	200 MHz 400 MHz 700 MHz
Advanced Microwave Radiometer (AMR) measures at each frequency (combined) to determine atmospheric water vapour and liquid water content. The main 23.8-GHz frequency is used to measure water vapour, the 18.7-GHz channel is highly sensitive to wind-driven variations in the sea surface and the 34-GHz channel for the correction for ocean surface and non-raining clouds.		

Instrument	**Centre Frequency**	**Bandwidth**
MWR (Sentinel-3)	23.8 GHz 36.5 GHz	400 MHz 1000 MHz
The MicroWave Radiometer (MWR) measures the thermal radiation emitted by Earth. The 23.8 GHz channel is used mainly to determine the delay of the altimeter pulse by tropospheric water vapour. The 36.5 GHz channel primarily addresses the delay from non-precipitating clouds.		

The following tables provide an overview of the frequency use of the active sensors (scatterometer) on the current NGSO MetSat satellites "Metop" (left) and on the second generation "Metop-SG" (right):

Instrument	**Centre Frequency**	**Bandwidth**
ASCAT (Metop)	5255 MHz	1 MHz
Advanced Scatterometer (ASCAT) Near-surface wind speeds and diections over global oceans. Scatterometer wind measurements are used for air-sea interaction, climate studies and are particularly useful for monitoring hurricanes.The data are also applied to the study of vegetation, soil moisture, polar ice, tracking Antarctic icebergs and global change.		

Instrument	**Centre Frequency**	**Bandwidth**
SCA (Metop-SG-B)	5355 MHz	2 MHz
The Scatterometry Mission (SCA) on Metop-SG is providing back-scattered signals in the 5.3 GHz band at higher resolution as its predecessor instrument ASCAT on Metop.		

The following tables provide an overview of the frequency use of the active sensors on the current NGSO (66° inclination) EESS/MetSat satellites “Jason-2/-3” and future “Jason-CS/Sentinel-6” (left) and the soon to be launched NGSO (polar) EESS satellites “Sentinel-3” (right):

Instrument	**Centre Frequency**	**Bandwidth**
POSEIDON-3 and 3B (Jason-2 & -3) POSEIDON-4 (Jason-CS / Sentinel-6)	5300 MHz 13.575 GHz	320 MHz 320 MHz
Poseidon-3 and -3B solid state altimeters measure sea level, wave heights and wind speed at 13.575 GHz and estimates atmospheric electron content at 5.300 GHz-		

Instrument	**Centre Frequency**	**Bandwidth**
SRAL (Sentinel-3)	5410 MHz 13.575 GHz	320 MHz 350 MHz
The Synthetic Aperture Radar Altimeter (SRAL) is a dual-frequency, nadir-looking microwave radar altimeter employing technologies from the CryoSat and Jason altimeter missions.		

The following table provides a summary overview of frequency band allocations in use or planned (green) to be used by EUMETSAT systems:

Communications	**Passive Sensing**		**Active Sensing**	**Other Instruments**
401 – 403 MHz	18.6 – 18.8 GHz	RR 5.340	5150 – 5250 MHz	1164 – 1215 MHz
406 – 406.1 MHz	23.6 – 24 GHz	RR 5.340	5250 – 5350 MHz	1215 – 1240 MHz
460 – 470 MHz	31.3 – 31.5 GHz	RR 5.340	5350 – 5460 MHz	1559 – 1610 MHz
1544 – 1545 MHz	33.65 - 34.35 GHz	RR 4.4	5360 – 5470 MHz	
1675 – 1710 MHz	36 - 37 GHz	shared	5470 – 5570 MHz	
2025 – 2110 MHz	50.2 – 50.4 GHz	RR 5.340	13.4 – 13.75 GHz	
2200 – 2290 MHz	52.6 – 54.25 GHz	RR 5.340		
3700 – 4200 MHz	54.25 – 59.3 GHz	shared		
7750 – 7900 MHz	86 - 92 GHz	RR 5.340		
8025 – 8400 MHz	114.25 – 116 GHz	RR 5.340		
10.7 – 12.5 GHz	116 – 122.25 GHz	shared		
25.5 – 27 GHz	155.5 – 158.5 GHz	shared		
	164 – 167 GHz	RR 5.340		
	174.8 – 182 GHz	shared		
	182 – 190 GHz	RR 5.340		
	190 – 191.8 GHz	shared		
	190 – 191.8 GHz	RR 5.340		
	226 – 231.5 GHz	RR 5.340		
	238 – 248 GHz	RR 4.4		
	313 – 356 GHz	RR 5.565		
	439 – 467 GHz	RR 5.565		
	657 – 692 GHz	RR 5.565		

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).

To identify and value the benefit for of each application is impossible. The UK government has tasked EUMETSAT to perform the measurement portfolio with the current and future satellite systems.

For example for the Metop second generation satellite system a cost/benefit analysis was performed in 2013 with the following conclusion:

BENEFIT AREA	***MINIMUM***	***LIKELY***
Protection of property and infrastructure	€1.3 billion/year	€5.5 billion/year
Added value to the European economy	€10 billion/year	€41 billion/year
Private use by European citizens	€4 billion/year	€15 billion/year
TOTAL	**€15 billion/year**	**€61 billion/year**

Figures do not allow for the hundreds of lives saved each year and the benefits to defense, security and emerging climate services.

Also not captured are additional benefits expected from the positive impact of increasingly accurate weather forecasts on the performance of downstream forecasts of weather-dependent phenomena, e.g. air quality and atmospheric pollution, marine environment and dispersion of oil spills.

And the benefits will increase further in the future as the:

- The accuracy of forecasts is likely to rise further as a result of improvements in Numerical Weather Prediction (NWP) models and observations.
- The relevance of warnings and decision-making support delivered by National Meteorological Services of Member States will further improve.
- Public and private decision making will improve and make better use of forecasts and warnings.
- The vulnerability of our society and economy (e.g. with the development of renewable energy) to weather and related hazards will continue to increase.
- More frequent high-impact weather events are expected in our changing climate, increasing further the avoided costs.

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

Society requests ever increasing accuracy. To achieve this meteorologists require more data and more parameters with higher measurement resolution and ideally immediate availability of the data from the satellites.

Like in any other areas, this trend imposed by the users goes towards more and higher resolution data, thus requiring higher data rates with consequently larger bandwidth for the downlink from the satellites and dissemination to the users.

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).

The demand for more measurements with higher resolution forces the next generation of GSO and NGSO MetSat systems (currently under development) to use the bands 7750 – 7900 MHz, 8025 – 8400 MHz and 25.5 – 27 GHz.

As there are no alternative bands available in the Radio Regulations, the long term availability and protection of these very few bands for the downlink from MetSat and EESS satellites on a global basis is of outmost importance.

In this context it should be noted that the band 7750 – 7900 MHz will be used by the next generation EUMETSAT Polar System (EPS-SG) to disseminate the mission data directly from the MetSat satellite to the users. Thus, it can be expected that there will be Earth stations also deployed in the UK (e.g. by the MetOffice and potentially the ECMWF).

For passive sensing the demand for additional measurement parameters means that in addition to the already used passive bands, which will continue to be used in the long term future to ensure continuity in the measurement data records, frequency bands above 200 GHz will also be exploited by future instruments.

The reason for all this is the fact that society realises the global warming and the ever increasing severe weathers mankind is facing globally. This drives the measurement requirements the national weather services (including the MetOffice) determine and request to be performed by the EUMETSAT MetSat satellites. Since a meteorological satellite system is designed and planned to operate over decates, such trend is always long term and global.

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.

One big challenge of course is to ensure that the radio frequency spectrum that is used by such MetSat systems over decades, either for communication purposes or active and passive measurements is kept available and free from interference. Every WRC there are a number of issues which seriously jeopardise this long term need.

It is to be noted that for such complex satellite systems like MetSat, which undergo a very long design and development process and a maximised operational lifetime to make most use of the public funds (> 2Billion Euro), any impact on the long term availability of the required and used spectrum resources due to wrong spectrum policy decisions or interference could have a tremendous long term implication on the availability of the measurement data to the users.

Considering the above, with all the requests from commercial operators for more spectrum, it is important that regulators continue to preserve the spectrum needed for the operation of EESS and MetSat satellite systems and their observations and the dissemination of the data to the users.

Keeping the allocated spectrum for EESS (active & passive) available and free from interference is a prerequisite to serve our users, the national meteorological services (NMS), thus it is required to:

- keep the purely passive bands in RR 5.340 free from interference, from in-band (all emissions are prohibited by RR 5.340) and out-of-band emissions, in particular in supporting mandatory limits as in RR Resolution 750,
- enforce conditions in the current shared bands that ensure long term usability of those bands by passive or active sensors (e.g. in the relevant portions of the 5 GHz and in the 13 GHz).

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?

No.

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?

5.12 gives a very wrong impression, only the passive bands listed in 5.340 are exclusively for passive usage in which all emissions are prohibited. All other bands, i.e. for communication, active sensing and many bands also allocated to EESS (passive) are already shared among a number of services, as mentioned in particular in ITU-R Report RS.2178. In this context it is to be noted that the sharing in all those bands is mostly successful. There are other services like the mobile service, which cannot share with any other service, despite the shared allocation status in the RR.

5.13 (Receiver filtering)
Learning from interference on existing instruments, improved filtering is introduced on newer/future instruments to the maximum possible.

5.13 (Global database)
Here it should be clarified that this idea of a global database is linked to the discussion on the introduction of RLANs in the band 5350 – 5470 MHz. Although in theory a possible mitigation technique among the need for some others, it is still lacking workable implementation scenarios. Who should be the entity to operate and maintenance of the database? How to realise from a regulatory perspective? Who is entitled to enter an instrument/satellite system into the database and at what time in the ITU filing process? What are the obligations for the RLAN operator with regard to this database? Who will be responsible for interference cases? etc.

In addition, and more concerning, in particular in frequency bands targeted by mass-market radio equipment (e.g. 5 GHz range), the issue of the compliance of these equipment as raised in ECC Report 192 is key in any successful implementation of such or any other mitigation technique.

5.14 (better coordination with other users)
This is successfully done. All bands used for communications to and from MetSat satellites are successfully shared with terrestrial services, either civil or military.

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?

From the Metsat and EESS perspective, it is rather difficult to foresee any additional mitigation opportunities apart from those usually implemented such as improved receiving filtering or frequency coordination. In any case, mitigation techniques cannot be implemented to the expense of any degradation of the data quality and availability.

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.

There are no short term needs for additional spectrum, it is rather the preservation of the already allocated spectrum resources that is needed against future applications that a requesting the regulators to designate spectrum for them, i.e. mobile broadband. Here operators of MetSat and EESS satellite systems will have to rely nearly exclusively on the bands 8025 – 8400 MHz and 25.5 – 27 GHz for the downlink of their measurement data, as well as on the band 7750 – 7900 MHz for the dissemination of high rate data from NGSO MetSats. Although, the number of ground stations in the UK is limited, there is a strong need for Ofcom to support keeping this spectrum available in the UK and on a global basis.

Also of particular importance for the operation of EESS and MetSat systems for Telemetry, Telecommand and Ranging are and continue to be for the forthcoming decades the S-Bands (2025 – 2110 MHz and 2200 – 2290 MHz). The identification of appropriate S-Band frequencies for new missions and further on coordinating and notifying those is a difficult and very long process. Not only that these bands have to be kept available for space operations, also successful frequency coordination in the framework of the ITU should be supported by Ofcom. This also includes that appropriate regulatory mechanisms have to be found and implemented for small satellites in other bands which otherwise have the potential to negatively affect the use and availability of the S-Band by traditional satellite systems.

For dissemination of meteorological satellite data, EUMETCast became a very important mechanism, using commercial satellites in Ku-Band and C-Band for regional/global distribution. Thus, always having sufficient transponder capacity available in both bands for allowing EUMETSAT to distribute the MetSat data this way is very important. For this regulators globally need to strike a balance between the spectrum requirements of upcoming mobile broadband systems in C-Band and the incumbent FSS and its long term spectrum requirements.