Strategic review of satellite and space science use of spectrum, Ofcom CFI , 4 June – 13 August 2015

All respondents

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

Airbus Defence and Space (ADS) would like to thank Ofcom for holding a review of spectrum used by the satellite and space science sector and for giving the opportunity to the different stakeholders to express their views, interests, provide long-term trends, information, and help Ofcom to refine the understanding of the sector.

Airbus provided a response to the Ofcom 's Spectrum Management Strategy end 2013.

We appreciate that the responses provided by our Group and by other trade associations of which we are an active member e.g. ESOA, GVF, UK Tech, etc) have contributed to the development of Ofcom positions for WRC 15. We are confident that the present CFI will confirm the understanding of the impact of the international context and regulation on our sector which by essence has a global reach.

We believe that there are two kinds of social economic benefits. In one hand the benefits are direct, meaning that they will develop the industry and the private sector, but in the other hand, most of them are indirect: the data will be use by governments and public for their daily business (as highlighted by ESA in Copernicus). The social economics benefits are enormous for the public and very valuable for the States in terms of cost of avoidance and security.

ADS regret the calendar chosen for this CFI and the rather short period of time to provide inputs. We would kindly recommend for the future to avoid scheduling such an important consultation few months ahead of a WRC.

Satellite Respondents

Airbus DS is a full member of ESOA (European Middle East and Africa Satellite Operators Association) and our views are fully represented in the Association response to this CFI on the Satellite communications part.

Airbus DS is happy to provide further contributions to the Questions when relevant to clarify our role in the satellite value chain and to the creation of economic value and benefits to the UK and their citizens.

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)?

We would like to draw Ofcom's attention to the following applications:

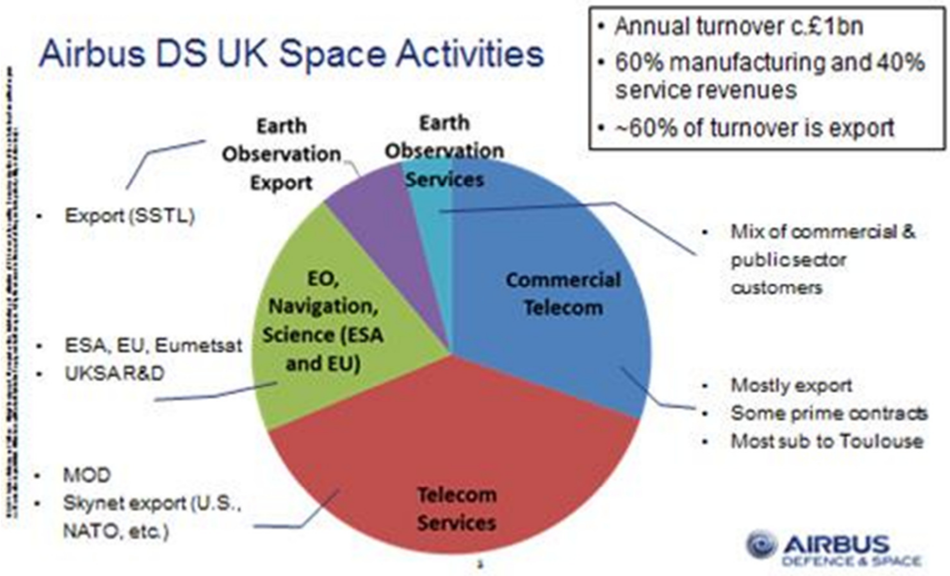
- Satellite broadcast/multicast offload at network edge (data distribution) of part of the traffic in order to optimize the infrastructure sizing;

- Very high speed broadband satellite systems backhauling to extend the reliable delivery of 5G services to public transportations including aircrafts, vessels as well as trains and buses.

Airbus DS /Space Systems has inherited the vast experience acquired by Europe's space pioneers, amounting to almost 50 years in the development and manufacture of launch vehicles and satellites. Airbus DS was a prime over 100 civilian and military telecoms satellites, and as a leader in broadcast satellites for data transmission, mobile communications and broadband internet access we manufacture or have the capabilities to manufacture spacecraft using all relevant ITU radio communications service (s) and applications reported in Table 1 of the CFI.

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?

Airbus DS is a world leader in satellite and payload equipment manufacturing ranking Top 2 through strong multi-domestic European roots.



The table I in Annex 1 in attachment summarize where Airbus DS is involved in the value chain against the various usages of spectrum. In the first table red squares indicate a significant business involvement. Grey squares indicate indirect or minor involvement as a user (eg of VSAT services).

The table II indicates the level of involvement of the UK parts of Airbus DS (the main satellite manufacturing occurs in Stevenage and Portsmouth). Dark green indicates major involvement meaning actual manufacturing, light green indicates minor UK involvement and the intermediate green indicates significant UK involvement.

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

Airbus DS is constantly looking ahead and preparing the future through continuous market and usage-driven innovation activities. This market-driven innovation approach is the key to our current world leader positioning. We lead the race on electric propulsion and our next generation platforms will integrate electric propulsion from the onset into the design.

Airbus DS offer now each and all of the three primary flexible payload capabilities: flexible coverage, flexible spectrum management and flexible power management.

These new platforms and payloads allow us to prepare the development of the next generation of broadband satellites, the so-called Terabit satellite, which will allow consumers internet subscriptions up to 100 Mbps.

Airbus DS Space Systems also gathers the complete set of competences, technologies and solutions to conceive and develop multi-layers systems and to address the challenge of large LEO/MEO constellations for the major internet actors.

Last 16th June 2015 Airbus DS was selected by OneWeb Ltd. as its industrial partner for the design and manufacturing of its fleet of microsatellites. This initial production of 900 satellites, each weighing less than 150 kilogrammes, is planned for launch into low Earth orbit beginning in 2018 to deliver affordable Internet access globally

Space science respondents

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

ADS is in line with of the list of applications and the definitions outlined in the CFI.

ADS would like to highlight that systems operating in the scientific and Earth observation services generate outputs that are essential to the understanding of our universe and the

future of our planet. Most of the value added created can hardly be estimated or compared to any man-made content. This concept is clearly expressed in the RSPG Report and opinion on ¨a Coordinated EU Spectrum Approach for Scientific Use of Radio Spectrum¨ (2006):
"In spectrum management it is becoming more and more important to estimate the value of different use of spectrum. In the case of scientific use of spectrum this may be quite difficult, as the benefits can relate to the society as a whole, may be difficult to foresee and may be realised over a very long period of time. Therefore, comparison with the economic benefits of services in the commercial field is often difficult."

Valuable information and parameters can be found in this report on quantifying the economic and societal value of scientific use of spectrum.

We also would like to draw Ofcom attention to the ITU-R Report RS.2178 *"The essential role and global importance of radio spectrum use for Earth observations and for related applications"* and to Resolution 673 (WRC-12) on *"The importance of Earth observation radio communication applications".*

In general, space science services produce benefits to different sectors:

- Economic
- Environmental
- Public Health
- Societal, Security
- Knowledge

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?

Commercial and Governmental use of the space science services shall be acknowledge as a result of this this public consultation. , Two aspects should be taken into account:

- the users that are receiving and using the data directly ,
- the users that benefit directly from the data but receive them indirectly (for example the agriculture sector which does not know from where the data come but their availability is vital for the sector).

About the value chain, some ancillary services could also be highlighted, for example:

- Financial and legal services for the manufacturing (Equipment manufacturers and Launch providers)
- Insurance and brokerage services for the operations (Earth station/Teleport operators, satellite operators)
- R&D and knowledge spill overs for the users
- The data provider is doing the analysis depending on the type of information requested. This value added segment is key to provide the best information to the customers.

Provide

- Manufacturer of (Turn-key) satellite systems for Earth observation, scientific, and navigation

(see PDF-presentation AirbusDS as separate document)

- Space and ground equipment for satellite control (Bus and payload) and payload data
- Launcher and launch service provider
- Satellite operator stand-alone and in partnerships
- Provider of raw and processed data as well as of value-added services in Earth observation (optical and radar)

Help to deliver?

- Supporting clients, partners, and customers to receive, process, and use data from EO, scientific and navigation satellites
- Providing technical support, (on-site) training, and education on EO and scientific systems and applications
- Provide high value product to the public services

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) do your organisation?

Use

Supplier, therefore no in-house of science data

Provide

- Manufacturer of (Turn-key) satellite systems for Earth observation, scientific, and navigation

(see PDF-presentation AirbusDS as separate document)

- Space and ground equipment for satellite control (Bus and payload) and payload data
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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:*

Airbus Defence and Space consider the detailed response provided by UK Space Agency to this CFI and the tables previously provided by ESA and EUMETSAT to Ofcom an exhaustive overview of the different frequency bands used by Space Science services for EESS active sensing, passive sensing and TT&C.

Please find below the frequency bands allocated to EESS active sensing with a definition of the main applications for these frequency bands.

Table 1 Frequency bands for EESS active sensing

Band	Allocations[1]	Main applications/ Remarks
1 215 – 1 300MHz	EESS (active) + SRS (active) Space-to-Earth	L-Band SAR: . For biomass estimation, land cover mapping, soil moisture measurements. (JAXA ALOS1+2)
3 100-3 300 MHz	EESS (active)	e.g. NovaSAR, UK, good for small satellites
5 250 – 5 570 MHz	EESS (active) + SRS (active)	- mapping and sea ice surveillance - medium penetration depth allows for vegetation monitoring, less influence by soil moisture (agriculture => biomass estimation, crop monitoring/classification)
8 550 – 8 650 MHz	EESS (active)	low penetration into the medium allows mapping and surveillance tasks, 3D modelling, site monitoring
9 300– 9 900 MHz	EESS (active) + SRS (active)	light and weather independent. Major applications are environmental monitoring, infrastructure monitoring, maritime applications => in future 1200MHz (AI1.12 WRC-15)
13.25 – 13.75 GHz	EESS (active) + SRS (active)	- Growing propagation losses - good for estimation of snow-water-equivalent (SWE)
17.2 – 17.3 GHz	EESS (active) + SRS (active)	
35.5 – 36.5 GHz	EESS (active) + SRS (active)	

[1] Services in small letters refer to an allocation with a secondary status

Band	Allocations[1]	Main applications/ Remarks
37.5 – 40.0 GHz	eess (active)	- precise elevation modelling is possible, as no penetration into the medium (vegetation) occurs - optimal for interferometric applications
94.0 – 94.1 GHz	EESS (active) + SRS (active)	
135.5 – 134 GHz	EESS (active)	

+TT&C in S/X-Band for telemetry, tracking and control subsystem and high-rate payload data (8 GHz) provides vital communication to and from the spacecraft.

- *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);*

It should be noted that different frequency bands are used for the same type of measurements but in order to have accurate and precise information, measurements need to be done in different frequency bands across the spectrum.
Another point is the need to have access to specific frequency band as in the case for example of water frequency resonance.

- *whether the applications use continuous or intermittent measurements;*

Vast majority of applications are using intermittent measurements (less than 7 sec per image)

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

The resolutions are limited by the allocated bandwidth, but it should be noted that a major market demand trend is to have very high resolution which means greater bandwidth.

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

The geography targeted by space science satellite is mainly global.

C-Band: notable focus is maritime

L-band: notable focus is land and ice

X-Band: notable focus is monitoring

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

The location of the gateway station(s) for TT&C and downlinking data can be anywhere, but is should be noted that the locations are not ubiquitous.
Key role of near polar locations.

- *the estimated number of users.*

As stated before, different sectors benefit from space science services:

- Economic
- Environmental
- Public Health
- Societal, Security
- Knowledge
- Direct use : all public agencies, governments
- Indirect use: all mankind

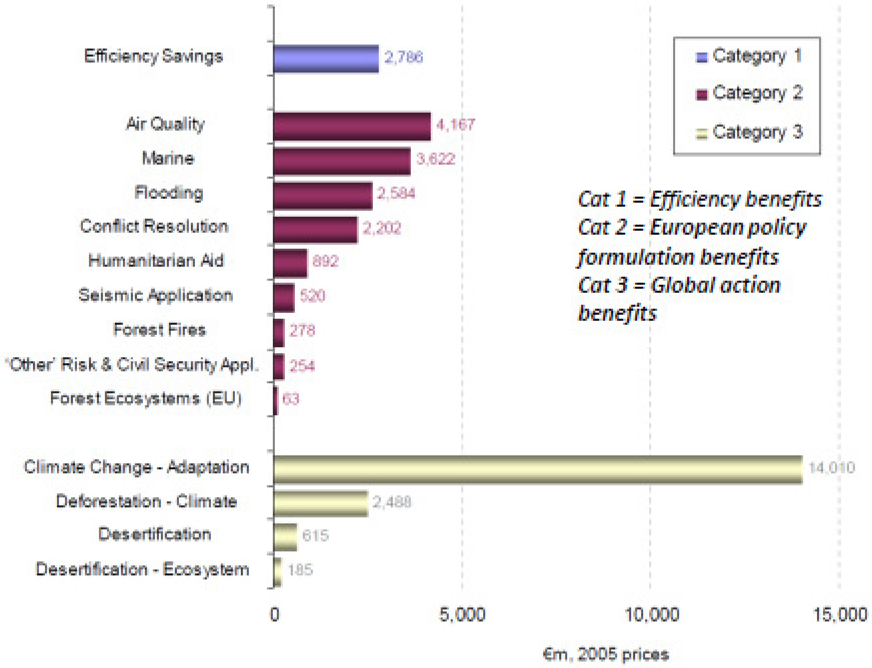
Question 17: For each of the space science applications you provide, please could you indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

As stated in the RSPG Report and opinion on ¨a Coordinated EU Spectrum Approach for Scientific Use of Radio Spectrum¨ (2006):

"Most of this societal value is incommensurable in financial terms, as they relate to preventing large losses of lives or threats to socio-political stability and security. However, scientific use of spectrum also has a direct impact in many economic areas, which can be estimated, and in producing economic spin-offs in technology and economic developments in energy, transportation, agriculture, communications, medicine, etc. "

As general information, the generated revenues for the satellite manufacturing industry worldwide were $11.4 billion in 2013. For the Earth observation services, the estimated revenue was in 2013 £1.4 billion worldwide. The satellite sector provides high-skilled jobs in UK, Europe and worldwide.

If we take the Copernicus example, which are satellite systems to create an autonomous and capable infrastructure for EO and geo information services for global environmental monitoring. Downstream revenues are expected to be up to £25 billion by 2030 (cumulated). The anticipated cumulative benefits will be up to £166 billion by 2030 (cumulated). Up to 83,000 jobs will be created between 2015 and 2030.



Summary of the main GMES Benefits by Policy Issue

Another example could be the illegal, unreported and unregulated Fishing (IUU), which is estimated to cost between €4 billion and €9 billion per year to the EU community. By means of NovaSAR-S, the first UK National Radar mission, UK is able to detect and track ship, and this to protect fisheries interest and UK citizens. This mission can also help with illegal immigration, smuggling detection. This mission can also be used for other matters, for example:

- For Emergency/security interest, it can monitor floods, landslides, infrastructure damage, can support anti-piracy
- For climate changes, monitor ice edge
- For exploration and topographic mapping
- For maritime, environmental and change monitoring, , it can detect and track iceberg
- For object identification

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

All observation is meant to be run continuously and in the long term, to identify trends and changes in the earth environment, climate, and geography. In order to continue the observation of current satellites and plan new missions, stability in spectrum allocation and regulation is necessary due to the lifetime of a mission between its development and the satellite lifetime.

Demands for earth observation measurements is expected to continue to increase from governmental, public and private bodies, including citizens and more societal business activities. Increased environmental awareness is also expected to be a driver for the sector with the objective for mankind to access more and more data to better understand our environment. In this matter, one of the major trends is the access to higher resolution images, which means an access to wider bandwidths for these missions.

Airbus Defence & Space would like to highlight two current topics:

- **The Copernicus Program , SAR technology**

The band 5 350-5 470 MHz is a part of the whole 5250-5570 MHz band allocated to the Earth Exploration Satellite Service (EESS) on a primary basis.

EESS contributes to the Copernicus Program (ex GMES) which establishes a European capacity for Earth observation. It is an EU led initiative carried out in partnership with the Member States and the European Space Agency (ESA).

The Copernicus program is set to make a step change by providing reliable, timely and accurate services to manage the environment, understand and mitigate the effects of climate change and help respond to crises. The success of this initiative relies on the provision of robust data, predominately from a fleet of Earth observation satellites called Sentinel and supplemented by data from Member States' satellites (e.g. TerraSAR-X, Pléiades and SPOT).

4.4 B€ has already been invested by the Member States, of which 2.4 B€ were for the space component a further 3.8 B€ has been committed for the 2014-2020 period.

The expected cumulative ROI over the 2014-2030 period is 29.4 B€ and 83 000 jobs should be created in Europe by 2030.

Five satellite missions, called Sentinel, will support the operational needs of Copernicus. For each of these 5 Sentinel missions up to 3 satellites will be launched.

Sentinel-1 and Sentinel-3 satellite series both have payloads that operate respectively in the bands 5 355-5 455 MHz and 5 250-5 570 MHz covering the entire 5 350-5 470 MHz band considered for a potential RLAN extension.

ESA has conducted technical studies in ITU – R and CEPT that demonstrate that sharing is not feasible between RLAN and satellites.

Therefore 2 Copernicus Sentinel missions are potentially directly impacted:

- Sentinel-1 CSAR – SAR instrument
- Sentinel-3 SRAL – Altimeter instrument

In addition to the Sentinel missions there are approximately 30 existing or planned contributory missions. These are missions from the European Space Agency, its Member States, EUMETSAT and other European or international third party mission operators that make part of their data available to the Copernicus program.

The Copernicus Data Warehouse provides comprehensive and coordinated access for all users to all Copernicus space data both from the Sentinel missions as well as the contributing missions through a single harmonized interface.

Airbus Defence and Space home countries, which include the UK, are encouraged to support the Copernicus program at EU, CEPT and ITU-R level in the long term to ensure its viability.

The adopted European Common Proposal (ECP) for WRC 15 on Agenda item 1.1 does not support the 5 350 – 5 470 MHz EESS (active) allocation for future use by RLAN.

However, under Agenda Item 10, CEPT support to study possible additional mitigation techniques to introduce wireless access systems (WAS) and radio LANs (RLAN) broadband in the frequency band 5 350 – 5 470 MHz.

Airbus DS intends to contribute to any further work on this matter having regard to the results of the compatibility studies if WRC-15 would decide it as a new Agenda Item for WRC-19.

- **EESS (WRC 15 AI 1.12 and 1.13):**

Airbus Defence and Space welcomes the support provided by Ofcom to the allocation of an additional frequency spectrum of 600 MHz to Earth Exploration Satellite Service (active) with a primary status by the upcoming WRC 15.

Space-borne radars operating in the EESS band, as described in Report ITU-R RS.2274, have demonstrated their important contributions to a large number of commercial, Governmental, scientific and geo-information applications which is also recognized in Resolution 673 (Rev.WRC-12). The growing demand for higher resolution radar pictures raises the need to further increase the bandwidth used for linear FM chirp radar transmission of the next generation of EESS Synthetic Aperture Radars (SAR).

The extension of the EESS in the 9 600 MHz range would enable the world leading Synthetic Aperture Radar on-board the next generation SAR satellites (e.g. TerraSAR-2). As shown in Report ITU-R RS.2274, the radar image resolutions would improve to better than 25 cm in case the transmission (chirp) bandwidth increases to 1200MHz, thus bringing SAR images into the order of magnitude of high-end space-based optical pictures, but independent from day light and cloud conditions.

ITU-R approved sharing studies exist with all incumbent terrestrial services show RF compatibilities of EESS and provide mitigation options in cases of rare less tolerable interference conditions.

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?

In addition to information under Q18, the following Table shows the range of frequency bands and their individual physical propagation characteristics with typical applications. It is important to note, that bandwidth demand for science services such as SAR are driven by physical laws and the intended image or other sensor resolutions are directly related to the applied bandwidth. So, different from communication services where bandwidth is mostly required to increase channel or system throughput capacity.

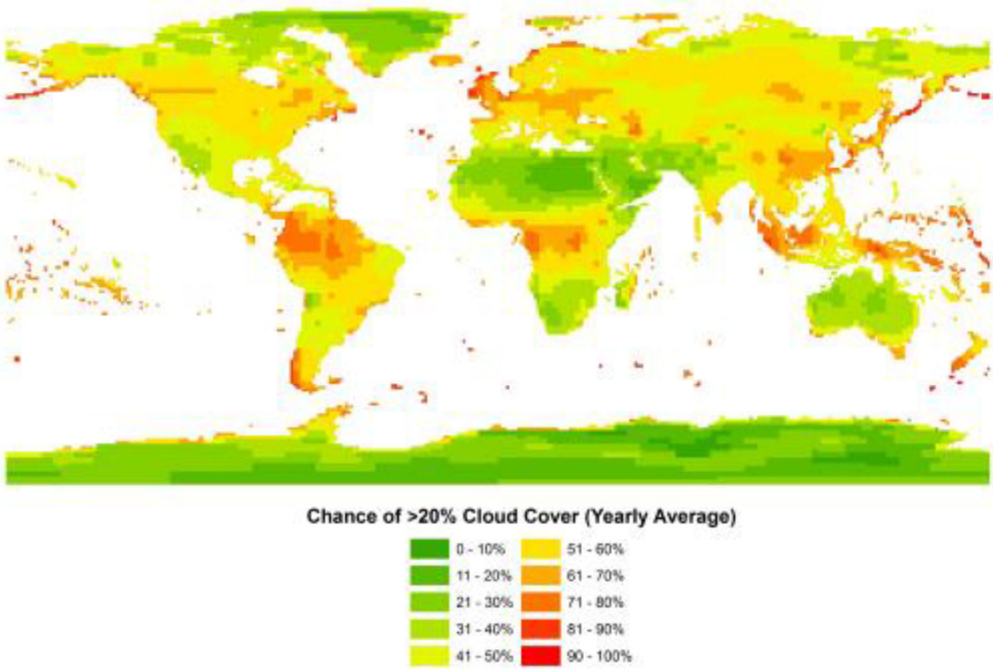
Band	Allocations[2]		Main applications/ Remarks
1 215 – 1 300MHz	EESS (active) + SRS (active) Space-to-Earth		Long wavelength allows for penetration into vegetation, especially high dense crops and forestry. For biomass estimation, land cover mapping, soil moisture measurements. (JAXA ALOS1+2)
3 100-3 300 MHz	EESS (active)		e.g. NovaSAR, UK
5 250 – 5 570 MHz	EESS (active) + SRS (active)		- mapping and sea ice surveillance - medium penetration depth allows for vegetation monitoring, less influence by soil moisture (agriculture => biomass estimation, crop monitoring/classification) - Propagation less affected by atmospheric conditions
8 550 – 8 650 MHz	EESS (active)		low penetration into the medium allows mapping and surveillance tasks, 3D modelling, site monitoring
9 300– 9 900 MHz	EESS (active) + SRS (active)		Highest resolution at still good propagation conditions (cloud/rain penetration) => in future 1200MHz
13.25 – 13.75 GHz	EESS (active) + SRS (active)		- Growing propagation losses - good for estimation of snow-water-equivalent (SWE) - precise elevation modelling is possible, as no penetration into the medium (vegetation) occurs - optimal for interferometric
17.2 – 17.3 GHz	EESS (active) + SRS (active)		
35.5 – 36.0 GHz	EESS (active) + SRS (active)		
37.5 – 40.0 GHz	eess (active)		
94.0 – 94.1 GHz	EESS (active) + SRS (active)		
130 – 134 GHz	EESS (active)		

2 Services in small letters refer to an allocation with a secondary status

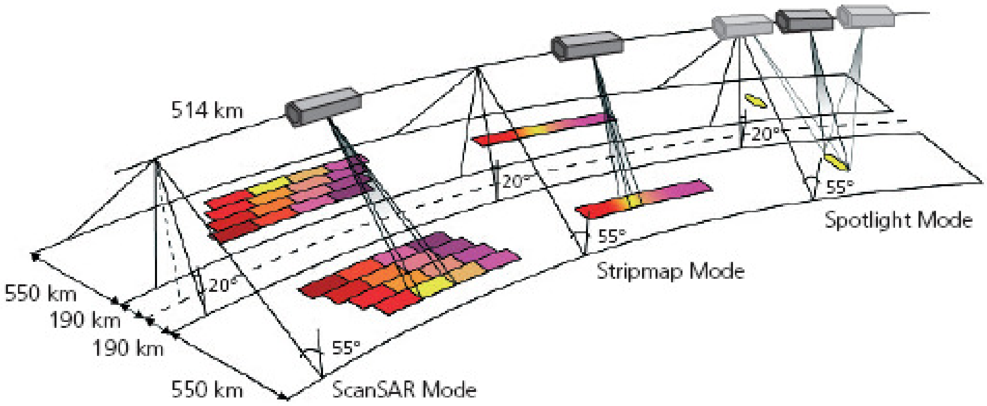
Band	Allocations[2]		Main applications/ Remarks
			applications

- the scale of the demand drivers;

The demands for SAR images depend on sometimes conflicting intentions, high penetration vs high image resolution, high weather independents vs. high carrier frequencies enabling high bandwidth (resolution), a.o. The Figure below shows the high chance of cloud cover in many populated regions showing the advantage of SAR being independent from sunlight and clouds.



The Figure below shows the typical modes of SAR operation ranging from large area at low resolution to spot area with highest resolution.



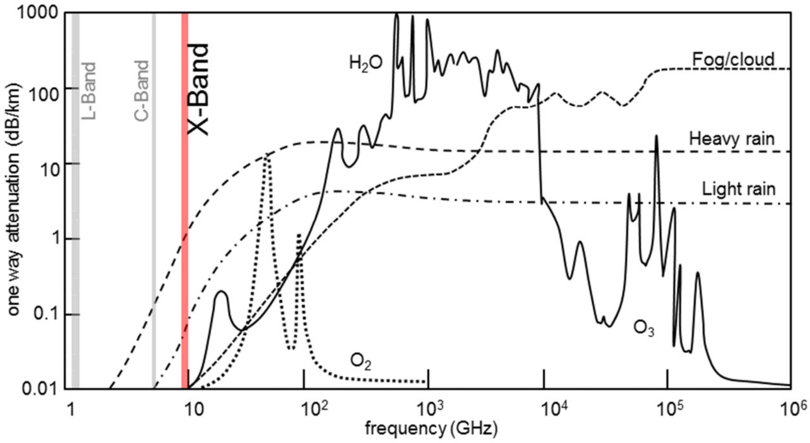
- the reason for additional demand (e.g. higher resolution radar data rates/bandwidth required) and whether this increased demand is for data delivery or for the taking of measurements;
- whether increased demand can only be met at specific frequencies and why;

as shown in the Table above, different frequency bands allow different observation at a wide range of image resolutions.

- Call for Input - Strategic review of satellite and space science use of spectrum

- any variations in demand drivers by geography (i.e. regional or global), and why;

the number of SAR satellites is limited worldwide, but they are all covering the full Earth's surface by using low Earth orbiting circular planes at sun-synchronous inclination angles (polar).



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

The demand for SAR observations is driven by geographic and topologic changes over long and very long periods of time (coastal regions, volcanoes, glaciers), although to use of spectrum is limited to pulses with wideband chirps.

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.

The use of frequency spectrum for Space Services should not be put at risk as the information gathered and its dissemination to policy makers, governments and public stakeholders is essential to preserve the world natural resources and our economies sustainable.

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?

None identified. The spectrum demand for space science worldwide, and in the UK, is likely to increase.

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?

Please find below the view of Airbus Defence andSpace on the different mitigation techniques proposed.

- *implementation of better EESS receiver filtering and/or sensor design to improve EESS compatibility with services in adjacent bands*

EESS filter are using up to date technology. They might still be improved but with an impact on the cost, the measurements and it will not solve the problem of out of band emissions from adjacent band systems which is from our experience the main source of current interferences. Indeed, there is no use to have sharp filter if adjacent band services do not as their out-of-band emissions will be the main source of interference. This can be useful only to get an equitable level of interference from the filtering of the emission in the adjacent bands and the emission of adjacent band services into the used frequency band.

- *development of new signal processing techniques to reduce the susceptibility of space science applications to interference*

Our signal processing techniques are at state of the art technology, and space industry are always working to improve these techniques. But these techniques are a solution from a limited number of sources of interferences; especially it cannot work for high density services used worldwide as for example IMT.

- *a global database of science satellites (including information such as orbital details, repeat period etc.) that might enable sharing with other spectrum users whilst avoiding those users causing interference to science satellites*

We have serious doubt about this solution, especially in the context of the 5350-5470 MHz frequency band, as first there is currently no evidence or experience that shows that such mitigation techniques may really work. Other challenges can be raised such as: who would be the responsible to manage such database, who will be the responsible in case of interference, how to guarantee that such a solution will be implemented and any illegal use will be prevented (as it was seen for RLAN devices with DFS).

- *better coordination between space science users and commercial spectrum users leading to greater geographic sharing of spectrum between these users, for example where frequencies used by radio astronomy sites can, with appropriate separation distances, be re-used for commercial co-ordination between radio astronomy sites*

In theory it works as far as no preference is given to commercial spectrum users. Experience shows us that it is not the case and therefore we do not support it.

More information about mitigation techniques can be found in Document 5A/TEMP/262, Annex 9 to Working Party 5A Chairman’s Report “compilation of technical information on techniques that could be used in RLAN deployments to facilitate sharing.

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?

No other mitigation opportunities have been identified on our side. We believe that sharing should be favoured between services that are compatible, and preferably with some successful experiences.

Unfortunately history has shown us that high density mobile services have real difficulty to share with other services and are not willing to share a frequency band on the long-term, aiming at the exclusive access to the spectrum.

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?

Airbus Defence & Space wishes again to underline the need to have long term and viable access to spectrum and regulatory certainty in order to enable investment and growth for the space sector.

ANNEX 1

	Equipment Manufacturer	Launch Providers	ES / Teleport Operator	Satellite Operator	Network & SP	Distributor	Content / Application Provider	End User
Satellites in General	Manufacturer of Ariane Launcher for all types of satellite	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FSS Civil	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	Yes	N/A	Normal VSAT usage typical of a large company
FSS Military	Satellites & Payloads & Payload Sub-systems User terminals	N/A	Military	Military Satellites	Military	Military	N/A	N/A
MSS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BSS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	Minor

RNSS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	Typical use of satnav & sat timing
Space Ops (TTC)	All satellites	N/A	Military Early Orbit Operations	Military Early Orbit Operations	Military Early Orbit Operations	Military Early Orbit Operations	Some provision of control sw	N/A
Inter-satellite	Occasional demand for hardware	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EESS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	Value added Earth Obs Services	N/A
SRS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RAS	No involvement	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Space Exploration Ops	Satellite TTC systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A

TABLE I

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MSS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BSS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	Minor
RNSS	Satellites & Payloads & Payload Sub-	N/A	N/A	N/A	N/A	N/A	N/A	Typical use of satnav & sat timing

	systems							
Space Ops (TTC)	All satellites	N/A	Military Early Orbit Operations	Military Early Orbit Operations	Military Early Orbit Operations	Military Early Orbit Operations	Some provision of control sw	N/A
Inter-satellite	Occasional demand for hardware	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EESS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	Value added Earth Obs Services	N/A
SRS	Satellites & Payloads & Payload Sub-systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RAS	No involvement	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Space Exploration Ops	Satellite TTC systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A

TABLE II