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techUK response to Ofcom consultation: Strategic review of satellite and space science use of spectrum

13th August 2015

Introduction

About techUK
techUK represents the companies and technologies that are defining today the world that we will live in tomorrow. In a very real sense techUK represents the future.

At the heart of tech in the UK is an ecosystem of 270,000 companies producing digital technologies, products and services. From east to west, north and south, from enterprise class organisations to established medium-sized businesses, growing small businesses and an exciting generation of tech start-ups: the UK is a hotbed of tech talent and techUK exists to represent the sector in its entirety.

Our role as techUK is to ensure that we seize the potential for good and address the disruptive new challenges that change and innovation always present. We work to understand the opportunities that technology provides; to support the companies and innovators that can realise those opportunities.

This underpins our simple vision to ensure that tech is good for the UK, the UK is good for tech and that tech is good for people.

About this consultation response
techUK has developed this response in consultation and co-ordination with the industry, UKspace trade association and its members, UK Space Agency and Satellite Applications Catapult. Due to tight deadlines and the closing date being in the holiday period, it was not possible to get responses from all interested parties and collate all responses received.

Summary of techUK position

Space technology and applications are seamlessly integrated in all aspects of our lives, often without the users being aware. In science, space related research has enabled huge strides to be made in our understanding of our own planet and its changing climate, our solar system and beyond. Satellite data is a crucial part of the accurate and longer term weather forecasting that modern society and many businesses now require. Satellite data, imagery, navigating and timing services play a crucial role in public safety and disaster relief. In defence and security, satellites provide essential communications and positioning enabling situational intelligence gathering and without it our battlefield and defensive capabilities will not be feasible. In commercial terms, satellites and space solutions play an essential role in communications and connectivity (telecommunications and broadband), broadcasting, navigation and transport (by sea, land and air). Commercial satellite data communications contributes to the establishment and resilient provision of cost effective communication links. Furthermore space technologies are forming an integral part of an increasing array of business and societal applications from transport, healthcare, agriculture and fisheries, to geological surveying, infrastructure monitoring and energy management. The global space economy is valued between US $ 256 billion and 314 billion (2013) and has been growing at a compound rate of 7.3 % in the last 8 years.

From the outset, UK has remained a significant nation in space activities. In terms of securing social and economic returns for its investment, there is no better example of a country ‘punching well above its weight’ than UK in space:

- **Manufacturing ('upstream' activities)**: UK has a leading reputation in the manufacture of space hardware and software. It is a world leader in the design and production of small, low cost satellites as well systems and subsystems for larger satellite missions. About 40 % of the world's commercial telecoms satellites include a significant element of UK manufacture[1]. UK developed software is to be found in many spacecraft and ground station systems.

- **Science services**: UK scientists and science institutions play a leading role in a wide range of science missions, obtaining and interpreting space-related data and developing world class scientific knowledge – both in terms of understanding our own planet as well as our solar system and beyond.

- **Satellite and space operations and applications ('downstream' activities)**: UK is a particularly strong player in the downstream applications of space. A supportive business and regulatory framework, together with a Government policy and innovation environment and pro technology consumers are vital for this.

As seen in the key statistics below, the UK space sector is a highly productive one with a GVA of £5.147 billion which is more than three times the UK average across the economy.

Space activities inspire young people to take an interest in science and technology as well as providing high value careers for those who choose to take up further education in scientific and technical fields. Some of these highly trained individuals may not undertake a role within the UK space sector, but take up roles in other highly skilled UK engineering sectors (e.g. automotive, medical, aerospace, etc) increasing the growth and jobs within the UK economy.

Summary of UK space sector vital statistics:

- High growth: UK space industry turnover is £ 11 billion (2012/13) composed principally of £907 million and £10.7 billion in the upstream and downstream activities, respectively. Direct broadcast satellite services represent a major part of downstream revenue. 31 % of UK space industry revenues are exports. The industry has been growing at a compound rate of 8.6 % since 2008 which is around 3 times that of the wider economy. UK has around 7 % of the global space and satellite market.
- High skills: The space industry employs 37,300 people directly and 78,300 through indirect and induced channels. It is an exceptionally skilled workforce with 3 out of 4 employees having higher degrees. No other sector in the UK has a higher average qualification level.
- High value: At a direct gross value added figure of £ 5.147 billion, the labour productivity of the sector is over 3 times that of the UK average.

[1] "UK Spectrum policy Forum: UK Spectrum Usage and Demand" First edition prepared by Real Wireless, March 2015

The Innovation and Growth Strategy (IGS), the joint Government and industry plan for the future development of the space sector has adopted an ambition to achieve market growth to £40 billion by 2030, i.e. to increase its share of the global market from the current 7.7 % to 10%. In terms of jobs, the IGS sets the bar at generating 100,000 jobs directly employed by the UK Space Sector by 2040. This equates to 1 in 300 of the UK working population working in the space sector by 2040.

All in all, the UK space sector makes major contributions to Government priorities on multiple fronts, from economic objectives to societal ones.

Spectrum is an essential ingredient to the functioning of space and satellite systems:

All the above space activities rely on the availability of spectrum. Although most of the bands allocated to Space services, ITU radio Regulations, are shared with other radio services, necessary arrangements are made either on a national, regional (at CEPT for instance) or global basis (at the ITU), to establish suitable conditions for sharing with other services. In some cases arrangement are either on a national or regional basis to access spectrum on an exclusive basis to meet specific deployment requirements. But given the nature of satellite markets and footprints, the sector requires most of the spectrum allocations to be on a worldwide basis. This allows satellites to be deployed to serve the global markets, and also to benefit from scale of production. The industry continually seeks the cooperation of spectrum managers to maintain international harmonisation in frequency allocation, and stop the position being eroded by any national plans that undermine international harmonisation.

Globally, space services have primary allocations totalling 30% of all sub-3 GHz spectrum, 65% of spectrum between 1 GHz and 10 GHz, and 82% of spectrum between 1 GHz and 100 GHz. However, only 3% is available on an exclusive basis for space/satellite services, and between 3 GHz and 10 GHz, no spectrum is allocated on an exclusive basis. Most commonly, the other allocated services are the fixed terrestrial services. However, sharing is not feasible when earth stations of satellite systems are deployed ubiquitously, e.g. mobile satellite terminals or satellite television (TVRO) terminals.

The challenging nature of the space environment together with the timescales for financing, developing, manufacturing, launching and bringing into operation of satellite systems, means that uncertainty on regulation and spectrum can undermine the business basis for planned and existing services. Any initiative on new sharing scenarios should be seen in this context. As the satellite industry upgrades and expands its services, to respond to increasing demand, it needs continued and dependable availability of spectrum for MSS, FSS and BSS in L, S, C, X, Ku, Ka and, in the future, Q/V bands.

techUK response to consultation questions

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

techUK welcomes Ofcom's efforts to understand the space industry's current (spectrum) landscape, future demand and technology trends, and the resulting implications for spectrum and Ofcom. We also welcome the recognition of the international nature of space industry footprints, markets and spectrum allocations. We of course understand and support Ofcom's priority to consider the interests of UK citizens and consumers. However we believe that in undertaking this review, Ofcom should also explicitly take into account the interests of the global opportunities for UK industry as a priority alongside UK consumer and citizen interests, since most satellite services by nature provide coverage on a global basis including the UK. The UK space sector is a valuable one supporting thousands of jobs as a direct result of its activities, with employee productivity of more than four times the national average. Significantly, both manufacturing and operations are capital intensive and require highly skilled people resulting in graduates filling nearly two-thirds of all jobs. As outlined above space applications underpin many areas of our economic and social lives. It is a high growth, high productivity sector which provides high value employment and exports its technologies and services all over the world. By its nature, much of the societal benefits (eg, in terms of climate understanding) and commercial markets are global. Space companies site themselves in the UK due to a combination of factors including the business environment, consumer adoption, Government policy and support as well as the certainty in the regulatory environment.

It is therefore vital that in undertaking this review, Ofcom adopts a high level criteria which goes beyond the priority for UK consumers and citizens and supports the UK space sector in terms of its global outlook and interests.

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 broadly agree with the overview. With regard to the 'end-user applications', we would add that commercial applications of earth observation data, imagery, navigation and accurate timing are an important and increasing market and should therefore be included.

We would also like to bring to the attention of Ofcom that today In addition, on the telecoms side, there are a few applications that are worth noting:

Correspondent services: these links provide international communications peering (typically between incumbent telco networks) for public telephony and data services. While small in volume these links can provide the only international connectivity for some nations, particularly in sub-Saharan Africa and some land-locked countries in Asia, where fibre networks have not yet arrived;

Backhaul services: these links can connect remote 'islands' of terrestrial connectivity to the core network, e.g. cellular base stations, wireless hubs, broadband DSLAMs. More and more satellite capacity is being used to backhaul mobile services (for example in providing 3G mobile backhaul in Europe. As capacity demands on terrestrial mobile networks continue to increase, such backhaul services could be an important sector for the satellite industry in the near future. These links can also provide a component of a nation's critical national infrastructure and these need to be recognised as a discrete application;

Continuity services (including resilience and redundancy): these links provide back-up services in the event of terrestrial infrastructure failure. They can apply to individual business/consumer/government services and telco network infrastructure, e.g. backhaul links.

Timing and synchronisation: the application of GNSS signals is critical to fixed and mobile terrestrial network operation. Although not a 'paid for' service as such, it needs to be recognised as a key component for the operation of critical national infrastructure.

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)?

techUK has no comments to add on this section.

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?

While the depicted value chain identifies the bulk of the categories of industry players, it is, depending on its intended purpose, potentially somewhat too simplistic.

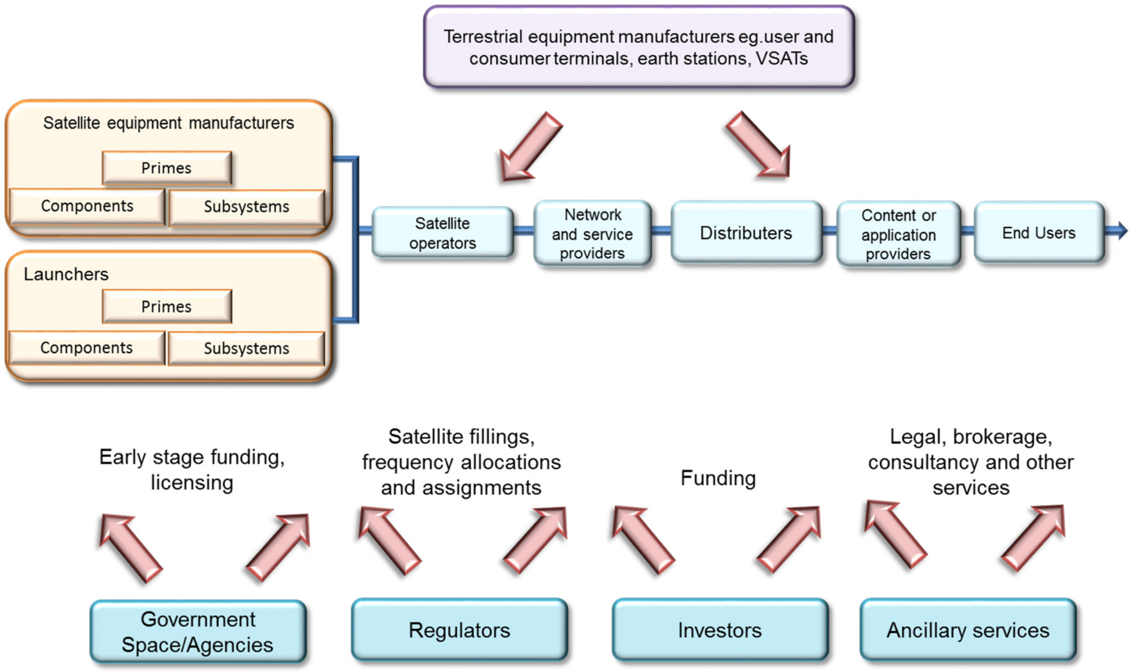
For example, the categorisation of 'equipment manufacturers' hides a complex ecosystem from satellite manufacturing to component and subsystem makers (including software providers) to system primes or integrators. In terms of the latter, the UK has particular world recognised skills in the manufacture of small satellites.

Similarly in the launcher category there is a value chain involving component, subsystem providers as well as integrators and launch service providers.

Twenty two satellite operators have registered satellite filings via the UK and a number of these have headquarters or major operations in the UK. Investment by UK satellite operators in procured Ka band satellite systems alone is approx. £3.4 billion. Such investment is set to increase in the coming few years; and this is without considering the huge investment in ground infrastructure and customer equipment, each of which are projected to increase radically in the coming years.

Furthermore, across the value chain, there are a number of players who provide important support functions, such as the Government (including the space and innovation agencies), regulator and private investors. Given the nature of space activities, the Government can be considered to be an important and intrinsic part of the value chain with its role in signposting future direction and emphasis for the industry through its policy on space, funding early stage development, provision of vital regulatory and licensing functions as well as being an important user of the resulting products and data from space.

An attempt to depict these roles is provided in the figure below.



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

techUK is the UK trade association for the technology industries. Our member companies are engaged in providing technologies and services across the digital economy, from digital communications and entertainment to healthcare, transport and Government markets. Of the 850 member companies, over 500 are SMEs.

With our position at the heart of the UK digital sector, two important roles for techUK are to provide:

(i) credible cross-industry perspectives and advice on Government and regulatory initiatives and
(ii) Provide the 'interconnections' for companies and sectors and develop market opportunities that will deliver the Innovation and Growth Strategy (IGS) ambition.

The satellite and space industry is an important sector for us and our members cover every element of the satellite value chain. In terms of space science, while on the whole not involved in research activities, our member companies undertake the design, development and manufacture of the associated satellite and space craft hardware.

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

techUK does not have information on specific frequency / channel usage information. However, the table below reproduced from The UK Spectrum Policy Forum's UK Spectrum Usage and Demand Report summarises the frequency bands available for space services

Band designation	**Approximate Frequency range (GHz)**	**Typical applications**	**Allocated satellite service**	**Other co-primary allocations in the RR**
P	0.23-0.47		MSS, RNSS	Terrestrial mobile
L	1-2	Used for MSS systems, using low earth orbit and geostationary systems. Also by RNSS systems in medium earth orbit	BSS, MSS, RNSS	Terrestrial mobile, fixed
S	2-3	Being brought into operation by two operators in Europe selected through the EU selection process. Systems may include complementary ground components (CGCs)	MSS, SOS, SRS	Mobile, fixed, EESS
C	3-7	Used for intercontinental links and links with high reliability requirements (including broadcast distribution, TT&C, feeder links for MSS systems). Also by RNSS systems in medium earth orbit	FSS, MSS, EESS	Mobile, fixed

		and a range of remote sensing satellites in low earth orbit		
X	7-8	Remote sensing satellites in low earth orbit	FSS (military), EESS, SOS, SRS	Fixed, radar
Ku	10-15	DTH TV, VSAT systems Remote sensing satellites in low earth orbit	FSS, BSS, EESS	Mobile, fixed, radar
Ka	17.3-31.0	Feeder links for BSS and High Throughput Satellites, for broadband Internet connectivity for fixed and mobile terminals. Remote sensing satellites in low earth orbit	FSS, MSS, BSS EESS	Fixed, radar
V	37-52	Test and development applications. Likely to see use for feeder links and super high throughput satellites in the future.	FSS, BSS, MSS	Fixed, potentially mobile
W	75-110		FSS, BSS	Fixed, potentially mobile

The UK allocations differ in some respects from the international table. There is no FSS allocation at 3.4GHz to 3.6GHz, or at 14.5GHz to 14.8GHz, in the UK, for instance.

The C and Ku bands are the most extensively utilised for commercial FSS services, while the Ka band is seeing rapid uptake and hefty new investments because the technological advances have helped the industry to exploit the full potential of the available large bandwidths for high capacity systems. Also, another key advantage in the higher frequency ranges of Ka band FSS satellite services is the high spectral efficiency which enables larger data carrying capacity with a Lower cost/MB produced relative to competing offerings.

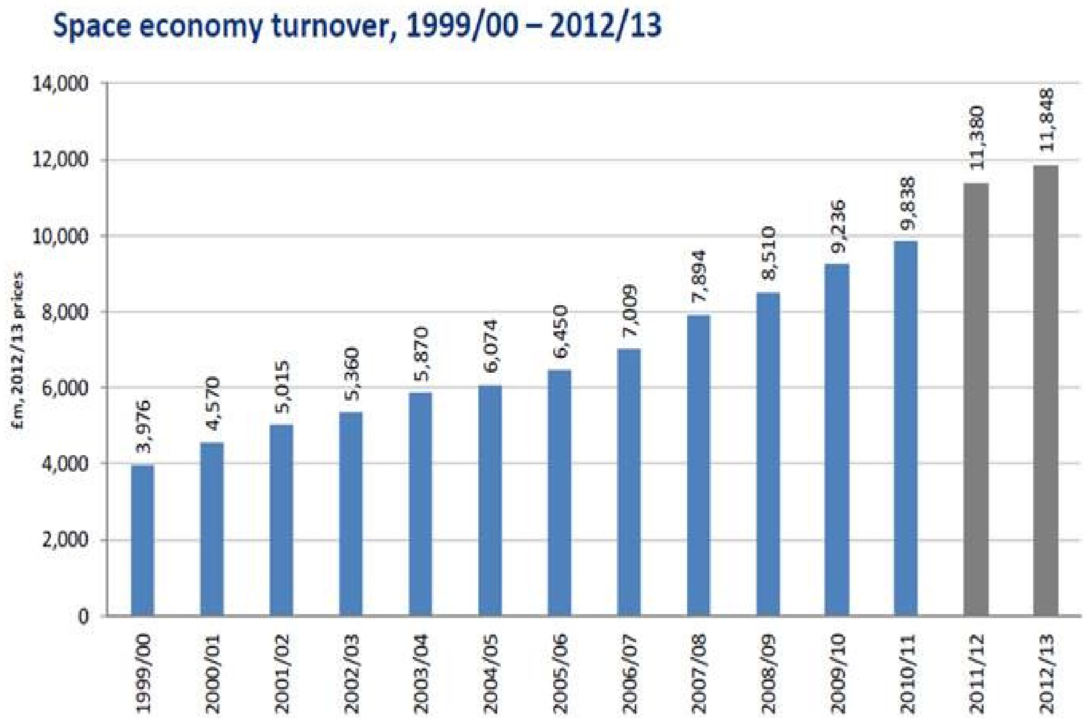
The lower frequency bands are especially relevant for satellite systems requiring high availability, since they are impacted less by rain fade.

Many satellite communications networks, elsewhere in the world, are supported by gateways in the UK and elsewhere in Europe, requiring use of the frequency bands relevant for those other localities e.g. C-Band. This is particularly true in the development of products requiring the use of spectrum and preparing the way when such products are manufactured for commercial use. Satellite players require the use of C-Band spectrum for uplink frequencies from 5.285GHz to 5.339GHz to develop and produce ground based transponders.

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)

The space industry is a valuable industrial sector for the UK which has an enviable and thriving space and satellite community. While the big players like Airbus, BAE, Inmarsat Lockheed Martin, QinetiQ, TAS-UK and Viasat are well known, 7 out of 10 organisations in the sector are SMEs, each with their own niche, making them successful and being able to thrive in a very competitive market.

As illustrated in the chart below, the UK space sector is a consistently high growth sector.



Note: 2011/12 and 2012/13 include additional space applications companies.
Source: London Economics analysis.

Key points[2] are:

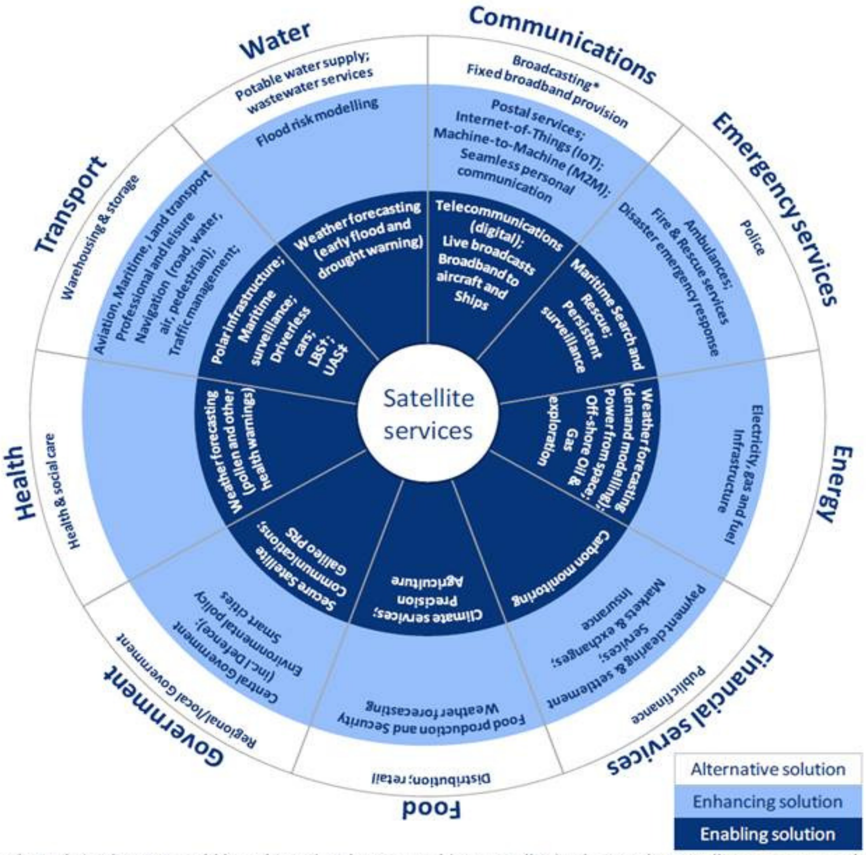
- The UK captures 6.3% to 7.7% of the global space economy turnover growing on average 8.8% per annum since 1999/00 and 8.6% since 2008/09 to reach a turnover of £11.85 billion in 2012/13.
- The UK space economy directly contributed £5.1 billion to UK GDP in 2012/13, exhibiting a high value-added share of 43.4% of turnover.

[2] The Case for Space 2015 - The impact of space on the UK economy; a study undertaken by London economics for the Satellite Applications Catapult, Innovate UK, UKspace and the UK Space Agency: http://www.ukspace.org/wp-content/uploads/2015/07/LE-Case-for-Space-2015-Full-Report.pdf

- Space directly supports an estimated 37,000 jobs, distributed across the UK. The total employment supported including indirect and induced effects is more than 115,000 jobs.
- 1 in every 300 jobs, by 2040, will be directly employed by the UK Space Sector.
- Space economy employees are highly skilled (3 in 4 hold a higher education qualification) and highly productive (labour productivity of £140,000 – over 3-times the UK average of £46,000).
- Even though most of the space manufacturing is concentrated in the East of England and downstream segments (operations and applications) are concentrated in London, the space economy benefits all regions of the UK.
- 7 in 10 organisations are SMEs, exhibiting more specialisation than larger enterprises.
- UK space exports in 2012/13 were estimated at £3.6 billion – an export share of 31% of turnover, more than double that of the UK economy as a whole (15%).
- The UK space industry is R&D intensive, with higher R&D expenditure than many high-technology sectors.

In terms of services to consumers and citizens, the space industry represents an important channel for reception of broadcast services, navigation and broadband connectivity. In the case of the latter, satellites services have an important role in providing superfast connectivity for domestic and business premises in the hardest to reach areas.

In terms of social benefits, satellites are helping us to understand Earth's complex systems and address climate change. Through space exploration, we have made great strides in the understanding of the solar systems and beyond. Satellite data is essential in weather forecasting – important for people and businesses. They play a vital role in emergency services and in humanitarian and disaster relief. The UK is a world leader in the technology and the analysis and interpretation of the data in all of these areas.



Note: 'Alternative solution': Application could be achieved with terrestrial (non-satellite) solutions, but satellite services may be chosen based on cost or performance grounds. 'Enhancing solution': Satellite services offer clear cost efficiency and/or performance superiority. 'Enabling solution': Applications for which satellite services offer an enabling solution.
*: Alternative solution for critical broadcasting, but enables live broadcasting. **: Location-Based Services. ***: Unmanned Aerial Systems.

Source: London Economics analysis of space applications.

The Case for Space Report also highlights that space plays an enabling, enhancing or alternative role in each of the UK's nine critical national infrastructures[3]. If satellite services were to be lost, all of the critical infrastructures that underpin UK society would be disrupted, as can be seen above.

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

In overall terms, the UK space economy has been growing at a compound rate of 8.6 % since 2008 and is forecast to grow to £40 billion by 2030.

In satellite communications, UK satellite operators provide a variety of services to address many different market segments: The rapid growth in mobile broadband connectivity is influencing demand for satellite services. In some parts of the world (including in Europe), satellites are used to provide backhaul for 2G, 3G and 4G mobile base stations. Furthermore, satellites are being used to provide mobile broadband connectivity to users on ships, aircraft, and land vehicles (e.g. trains), and also to provide mobile broadband access to individuals in remote areas (e.g news journalists). New systems operating in Ka-band, using "Earth Stations on Mobile Platforms (ESOMPs)" are being brought into use to serve the rapidly expanding market. These applications

[3] http://www.cpni.gov.uk/about/cni/

are provided from satellites operating in the C band, L band, S band, Ku band and high throughout Ka band spectrum.

Key advantages of Ka band:

- High data rate: Higher frequency range and spectral efficiency enables larger data carrying capacity – Ka-band wide transponders (300–600 MHz) are 10 fold compared to Ku-band transponders (27–54 MHz)
- High efficiency rate: Multiple spot beams are used to cover the same territory. Frequency re-use allows depth of coverage – Ka frequencies (~30 GHz uplink & ~20 GHz downlink) twice those used by Ku (~14 GHz uplink and ~12 GHz downlink)
- Cost effective: Lowest cost/MB produced relative to competing offerings. Customer equipment (dish + modem) is cheaper and easier to install.
- Large addressable market: Cheaper than traditional Ku-band markets (milsatcom, enterprise VSAT, mobile backhaul) as well as new markets (consumer broadband, IP trunking)

The take up of Ka band is accelerating, and the UK operators are deploying regional and global systems to meet the demand for broadband, Direct to Home (DTH) and other applications throughout the world. As stated earlier, the collective investments made so far by UK based operators in Ka band satellite systems alone amounts to around £3.4 Bn. Uncertainty on future access to the spectrum will undermine this and future investment.

In terms of DTH satellite broadcast services, the development of Advanced TV services is already underway. These will support far larger numbers of channels, Ultra-HD quality, 4K screens, interactivity, new advertising formats, multiscreen viewing and other changes. The continuing growth of DTH rests heavily on a model in which broadcast is optimal for the most heavily demanded content and for top quality linear video, while broadband is exploited for on-demand, time-shift, 'long tail' and user-generated content. In practice, this is being adopted by many service providers already.

Satellites have a unique capability to provide mobile broadband to hard-to-reach areas and on mobile platforms such as ships and aircraft. The rapidly growing consumption of mobile broadband in the UK and abroad means that ubiquitous coverage is becoming more important. It is also important that satellite-based systems can provide data rates commensurate with those provided by terrestrial systems. These factors will drive demand for more satellite systems capable of mobile broadband and will drive increasing need for more spectrum to meet increasing bandwidth requirements.

An important trend, which in in some regions will help expand the range of services satellite can deliver, while reducing costs to consumers, will be hybrid services, in which terrestrial and satellite spectrum and networks are combined.

L-band frequencies used for RNSS applications such as by the GPS and Galileo satellite constellations are critical for a wide range of applications and require protection to ensure sustainable operation.

The EU is also expected to spend approximately €7 billion (£5 billion) by 2020 on satellite navigation, and this investment is expected to bring considerable rewards. Independent studies show that Galileo will deliver around €90 billion (£65 billion) to the EU economy over the first 20 years of operation. Today, positioning and timing signals provided by satellite navigation systems are used in many critical areas of the economy, including power grid synchronization, electronic trading and mobile phone networks, effective road, sea and air traffic management, in-car navigation, search and rescue service to mention but a few examples. Like the Internet, a global navigation satellite system is a service enabler rather than a standalone service. It acts as a catalyst for economic activities, leading to the creation of added value and jobs in a wide range of sectors such as space, receivers and applications industries. It will also generate socioeconomic benefits for society as a whole, through for example more effective transport systems, more effective rescue operations, etc.

The C and Ku bands are the most extensively utilised for commercial FSS services, while the Ka band is seeing rapid uptake and hefty new investments because the technological advances have helped the industry to unleash the full potential of available large bandwidths for high capacity systems. Increase in usage of these key bands is expected to continue to show signs of growth, this growth to be particularly rapid in the Ka spectrum. An important trend will be the convergence of BSS, FSS and MSS services in all these bands.

The C-band is under increasing pressure from terrestrial mobile services, which means the satellite players are particularly keen to protect the C, Ku and Ka bands to ensure sustainable and viable access to the spectrum is maintained in order to meet the increased demand, now and for the future.

In Europe Solaris (Echostar), Inmarsat, Eutelsat and Avanti plan the deployment by 2016-17 of at least 2 GHz MSS/FSS band satellite services with complementary ground components (CGC).

Ka band offers wider bandwidths compared to lower frequencies. The take up of Ka band is accelerating, and the UK operators are deploying regional and global systems to meet the demand for broadband, DTH and other applications throughout the world. This opens up the opportunity for satellite to have an important role in a '5G' hybrid network, though this will rely on developing suitable business and network models.

Satellite can also deliver high capacity two way 'broadband' services for complementary coverage to fixed or terrestrial wireless networks outside major urban and sub-urban areas.

As noted earlier, satellites can deliver Internet access services at terminal speeds up to 100 Mbps or more to very large numbers of small user terminals designed for mass market price points. As an example, one HCS satellite in operation today serves over 700,000 customers with individual user speeds of 15 Mbps to the user and 3 Mbps return and capacity caps that start at 10 GB per month for the most basic service plans, and next generation HCS satellites are planned to offer speeds at rates equivalent to UK Superfast service and beyond.

Novel satellite transmission technologies, spectrum utilisation technologies and receive/modem, network structures will rapidly mature and develop in the coming years.

Question 9: For each of the satellite applications you use, provide or help deliver what do you see as the a) current demand trends; and b) underlying current and likely future drivers of demand for the satellite application(s) your organisation uses or provides? Please include in your response for both a) and b) above: - the scale and future impact of the trends/drivers on demand; - any variations in the type and scale of trends/drivers by geography (i.e. in the UK, the rest of Europe, and other parts of the world where this may be relevant to UK use) and why; - whether future demand is expected to be

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

See answer to Q 8

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.

Satellites by nature have multinational footprints. The time to finance, develop, build, qualify, launch and bring satellite systems into use can take over a decade.

Satellite players therefore count on the continued long term availability of existing ITU primary allocated or co-primary allocated satellite spectrum to MSS, FSS and BSS in L, S, C, X, Ku, Ka and Q/V bands to enable the continued development of new innovative satellite systems capable of offering a wide range of advanced MSS / FSS / BSS services.

Access to interference free spectrum is an increasing problem that can lead to localised quasi-congestion where specific frequencies can become sterilised for satellite services through poor local enforcement. This is particularly so in C-band which is shared with terrestrial wireless systems. The problem is most acute in Africa where the wireless environment is not as well managed as it is in other parts of the world.

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?

Within the constraints of the developing, launching and working in the space environment, the satellite industry is continuously striving to improve the efficiency with which scarce spectrum is used. Some industry trends include:

- Increasingly efficient use of lower frequency spectrum e.g. with multi-spotbeam/high gain satellite antennas (22m unfurlable antennas are already in use)
- Frequency reuse and sharing of same spectrum slots by multiple satellites; example of this are High Throughput Satellites (HTS) with multibeam payloads and improved frequency reuse techniques
- Increasing use of complementary ground components (terrestrial infill using ground based stations at fixed locations, in space spectrum, to increase availability). These can be simple satellite signal repeaters, but more commonly cellular base stations. Such techniques are being developed for the S-band MSS allocations in particular
- Terminal technology with very high pointing accuracy to improve mobile QoS and frequency re-use especially on ships and aircraft
- Increasing development of smaller terminals, consistent with conventional FSS VSATs, which in turn opens up the FSS bands for mobility, especially the Ka-band
- Rapid development of integrated circuit technology, smart terminals and low cost memory increasingly supports smarter and cheaper consumer equipment with more integrated functionality, though it is worth noting that the same

trends also apply in terrestrial services, which have greater market size and economies of scale

While some of these trends have the effect of reducing spectrum requirements if taken on their own, the overall trend is for the need for more spectrum, considering in particular:

- Increasing data rates in terrestrial fixed, broadcasting and mobile networks, which lead to demand for larger frequency bands for satellite services
- Technology improvements to systems and grounds stations which make satellite services more affordable, thereby increasing uptake
- Technology improvements which allow satellites to operate in larger frequency bands, which support more users, which lowers per user costs.

As noted elsewhere, there is considerable spectrum sharing between satellites and other (terrestrial) users, particularly between fixed satellite services and fixed (terrestrial services). However sharing between networks with a point to multipoint configuration, particularly with ubiquitous terminals (either satellite or terrestrial related) presents considerable difficulties. In these circumstances, existing registered systems may /could well be protected, however the prohibiting factor often is the prospect of denying access to the spectrum for unlicensed users or future systems.

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?

Dynamic spectrum access or use of database techniques are being studied with the potential to increase the ability to share but these techniques are at an early stage with respect to application for satellite systems. One of the difficulty that can be foreseen is the large difference in signal levels between terrestrial and satellite systems

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.

As discussed under Q10, access to interference free spectrum is an increasing problem that can lead to localised quasi-congestion where specific frequencies can become sterilised for satellite services through poor local enforcement. This is particularly so in C-band where terrestrial wireless systems are now allowed shared access. The problem is most acute in Africa where the wireless environment is not as well managed as it is in other parts of the world. Any action that could be taken at the international level to encourage and/or help some under-resourced national regulators to operate an effective coordination regime for shared satellite and terrestrial bands would be welcome.

The Space Innovation and Growth Strategy 2014-2030 asked that "Ofcom should prioritise the interests of UK satellite operator companies creating wealth, employment and taxes in the UK, in matters related to access to international satellite spectrum allocated by the International Telecommunication Union (ITU), treatment of satellite network filings by the UK to the ITU and to framing of international satellite regulations at the ITU".

In response the Government agreed that "Ofcom will continue to develop its approach to satellite and spectrum issues in close consultation with the UK space industry". We therefore encourage Ofcom to ensure sustainable protection for existing and planned fixed satellite services spectrum and spectrum use policies.

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?

With the clarifications provided in the answer to Question 4, we agree. It should also be noted that in the case of the scientific environment in some cases, a number of the functions depicted in the value chain may well be carried out by the same institution or group of institutions.

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.

Please see answer to Question 5

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.

Earth Observation:

All EO satellites (active and passive, radar and optical) require ever increasing bandwidths for data downlink. There is a drive for more frequent observations and persistent surveillance for security applications. This combined with the trend for EO satellites to become more affordable is leading to satellite constellations becoming more common. This results in a significantly higher bandwidth requirement, including permanent links at Ka band to satellites in Geostationary orbit such as the European Data Relay Satellite (EDRS)

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 synthetic aperture radar system, NovaSAR-S, uses the S-Band allocation of 3.1 to 3.3 GHz to deliver all weather medium resolution Earth observation data night and day at a price similar to traditional optical missions. It is priced significantly lower than any other SAR platform currently on the market, by leveraging highly efficient S-band solid state technology.

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 Government 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.

In terms of meteorological services (MetSats), the required satellite spectrum spans many differing frequencies, but of particular importance is the protection of passive bands (such as 1400-1427 MHz, 1068-1070 GHz, 15.35-15.40 GHz) so that the constituents and variables sampled in these unique atmospheric windows are able to be measured without any interference.

The Met Office has interest in the following frequency bands for UK use in the range up to 15 GHz from a satellite perspective:

- 1 151 – 1 214MHz GPS and Galileo
- 1 559 - 1 610 MHz GPS, Galileo and GLONASS
- 1 217.6-1 237.6 MHz and 1 565.42-1 585.42 MHz for GPS water vapour sensing;
- 1 690-1 710 MHz for reception of polar orbiting met satellites at Exeter
- 5 200-5 300 MHz EESS active to provide info on sea level, wave heights and ocean surface winds
- 6 425-7 250 MHz for info on sea surface temperatures
- 7 450-7 550 MHz used for reception of data from geostationary met satellites
- 7 750-7 900 MHz used for reception of data from polar orbiting met satellites
- 8 025-8 215 MHz Terra and Aqua satellite data
- 10.60-10.68 GHz used to provide info on surface rainfall rate and precipitation over oceans
- 10.7-12.5 GHz Eumetcast & satellite TV reception
- 13.40-13.75 GHz to provide info on ocean surface winds

Additionally there are some frequencies which must be retained due to use in Europe by Met satellite operators. These are 1 675-16 90 MHz; 2 025-2 110 MHz; 2 200-2 290 MHz. Additionally sea surface height from the Jason altimeter at 5.3GHz has strong Met support.

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.

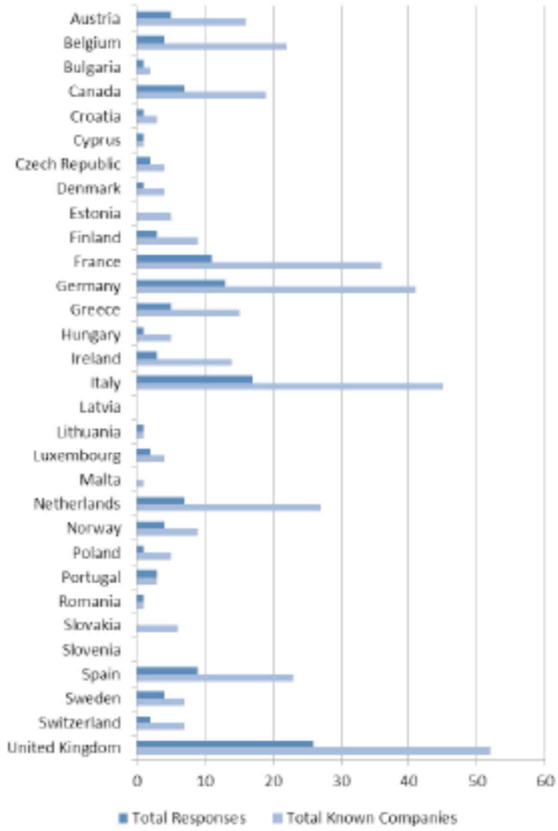
Question 17: For each of the space science applications you provide, please could you indicate how UK consumers and citizens benefit from their use? Where possible please also provide an indication of the scale of the benefits (either qualitatively or quantitatively).

Earth Observation applications are used across a wide range of business and consumer sectors including:

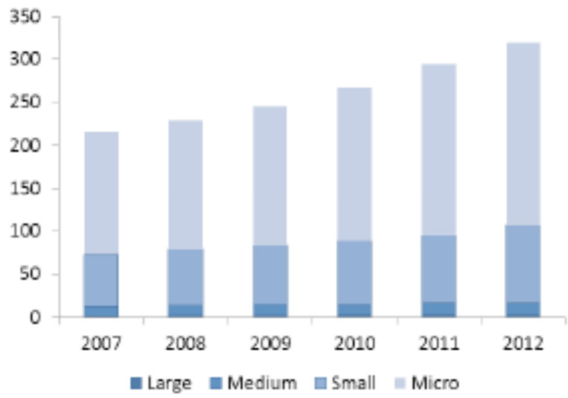
- Climate understanding and environmental protection
- Public protection and disaster relief
- Weather forecasting
- Energy – oil & gas and alternative energy e.g. wind farms
- Defence and security
- Productivity and efficiency improvements in agriculture and fisheries
- Civil infrastructure planning and monitoring – e.g. rail and tunnel subsistence
- Navigation & Timing

In respect of Earth Observation / Geo-Information applications 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.

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. Many of the applications require local knowledge or are driven by local, governmental needs for information – often linked to European directives such as land cover and use (Corine, Inspire) and agriculture. We expect this trend for new companies to appear in all EU member States to continue, in part driven by the Copernicus programme.



Geographical distribution of companies



Growth in the number of companies

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.

Total sector revenues (m€) over the period 2006 to 2012

In respect of the meteorological public good benefit, the Latest Public Weather Service Value for Money Review - March 2015 concludes with high confidence that the benefits of the Public weather Service (PWS) are:

- very likely to exceed £1bn per annum and
- likely to be close to £1.5bn per annum

These and other papers referenced in the report were used to access the economic value of weather forecasts to the following sectors:

- Public
- Aviation
- Civil Contingency
- Land Transport
- Flood Damage Avoidance
- Storm Damage Avoidance
- Added Value to the Economy

The purpose of the PWS is to help protect lives, property and infrastructure from weather impacts, and to contribute to UK economic growth through the effective use of weather information.

All weather services in the UK are dependent on the PWS's investment in the National Capability, which in turn is dependent upon the International Infrastructure of global exchange of data and weather satellites.

Value to the economy by sector

Sector	**Value (per annum)**
Public	£480m
Aviation	£400m
Land Transport	£100m
Flood damage avoidance	£64m
Storm damage avoidance	£80m
Added value to the Economy	£400m

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

EO Observation has advanced greatly over the last 30 years, meeting government objectives and generating wealth for the nation. During that time, EO science has revolutionised virtually all areas of earth, geophysical and environmental science - and the UK has become world class in several areas. Today, EO derived data is widely available at greater levels of detail than ever before, and increasingly the public will expect EO information to be made widely available. There is an increasing market for EO data and it is expected that the sector will start to achieve commercial viability as the costs of the collection systems decrease and the number of applications for the data increase.

Globally, the public investment in EO equated to £4.2 billion in 2008, with Copernicus alone representing more than £1.5 billion investment in Europe. There are expected to be 360 EO-related launches in the next decade, up from 164 during the previous one. The estimated revenues of the EO services industry in 2013 are £1.4 billion in 2013 and the anticipated cumulative benefits of the EU Copernicus program are up to £166 billion by 2030, with up to 83,000 high skilled jobs provided between 2015 -30 in Europe.

A specific theme in which the UK could establish a leading capability and that is expected to emerge in the 2010-2020 decade is the use of constellations – groupings of satellites operating together to provide significantly enhanced area coverage rates and timeliness of data delivery. These systems will be expected to open up significant markets which will be able to help both the development of the commercial markets and governments to deliver on the grand challenges imposed on society by changes such as climate, environmental stress and national & international security. Thus, the vision for EO over the next ten years is to place the UK in a position to drive and benefit from the anticipated market growth. This will require the engagement of the investment community and non-space players and partners to unlock new markets, giving fresh impetus to market development through lower cost missions, more and better sensors and more capacity to handle and process ever increasing data volumes.

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; 32 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; 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).

In the near term i.e. in the next 5 years, as EO applications grow there will be a requirements for use of X band EESS with an extended worldwide allocation up to 600 MHz by WRC 15 (AI 1.12), to provide higher resolution images in all weather conditions. A proposal is to be made to WRC 15 (A1.1.11) to allocate the 7-8 GHz band to EESS Earth to Space for high rate payload control and data links given S band congestion.

In addition, the use of the 25.5 – 27 GHz band is proposed for EESS Space to Earth to provide an increased payload data downlink capacity. Both ESA and EUMETSAT (MTG) are already moving from X EESS to Ka EESS band.

In the longer term, i.e. in the 10-20 year timeframe, the spectrum requirements for data downlink will be driven by the very large data rates derived from 4D, very high resolution imaging.

Operation of active EO sensors will continue to move into the higher frequency bands (Ku, Ka, V and W) with SAR sensors operating in all-weather conditions.

There is 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 global environmental monitoring can only be achieved by correspondingly transmission bandwidth.

A chirp transmission bandwidth of 1 200 MHz is to be available around 9400 MHz. Such a bandwidth requires an extension of the current EESS (active) allocation by 600 MHz to enable unprecedented features for long-term (4d, i.e.3d space dimensions and one time dimension) global monitoring as well as for environmental monitoring and land-use purposes.

It is to be recognised that the allocation to the EESS around 9 600 MHz combines the advantage of a largest possible bandwidth at the lowest possible frequency regarding propagation conditions.

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.

techUK has no comment to add

Question 21: Are there any future developments, such as the radio astronomy SKA, that could reduce the demand for space science spectrum in the UK? Question 22: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? To what extent do you believe that these mitigations apply only to certain applications?

techUK has no comment to add

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?
techUK has no comment to add

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

techUK has no comment to add