Satellite Applications Catapult

The Satellite Applications Catapult Ltd is a not-for-profit research organisation which acts as a neutral trusted entry point to an entire network of UK expertise in applications development across government, academia and industry. The company's primary purpose is to promote, develop and facilitate the commercialisation and advancement of the satellite applications industry.

The Catapult brings together multi-disciplinary and skilled teams to generate ideas and solutions in an open innovative and collaborative environment. We also have a wide range of facilities, platforms and laboratories to enable the best businesses, researchers and end-users to work together to develop new satellite-based products, services and applications - translating ideas from concept to market.

General

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

The Satellite Applications Catapult understands the reasons for using the ITU classifications, however believes this has limitations. For example, the commercial market for Earth Observation (EO) is included under Space Science. This classification does not reflect the fact that there is a significant commercial market, as well as a Space Science sector. In simple terms, one could consider the Satellite Sector as moving signals around and Space Science as the creation of knowledge from the data which is processed into information. This knowledge has a commercial as well as social and environmental value for those that own it and turn it into applications for end users. This commercial market (excluding defence procurement) was valued at about US$0.5 billion in 2012 according to Euroconsult (Satellite-based Earth Observation, Market Prospects to 2022).

Satellite Sector Overview

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 radio-communications service(s)?

The Satellite Applications Catapult agrees with the broad overview of the satellite sector. We have highlighted the commercial market from Earth Observation (EO) data under Question 3. It should be noted that ‘Military and government’ is included under Satellite Sector, but is not specifically listed under Space Science, yet uses services categorised under Space Science for military intelligence. Whilst historically ‘Military and government’ had their own satellites for their own purposes this is being increasingly replaced by being anchor tenants on commercial satellites or simply placing contracts with commercial providers. An example of this is DigitalGlobe in the US where US Government revenue is approximately two-thirds of its total revenue, the remaining third is commercial.

Science Sector Overview

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

The Satellite Applications Catapult largely agrees with the list of applications however would prefer a new overarching term to cover the two separate parts of this sector:

- Space science: Where the output is for science research which ultimately has significant social and environmental benefit, for example climate change studies.
- Commercial and operational Earth observation (EO): This is focussed on end user need and commercial growth. It should be viewed as the application of science for real world problems and this has already been shown to have a significant commercial value. We would expect Airbus Defence & Space to have commercial revenues from EO data of a similar magnitude to its US competitor (DigitalGlobe) which reported US$259 million in 2014 (excluding US Government revenue). The arrival of new satellites producing higher quality data more frequently should increase the revenue potential. We are already seeing the commercial sector dictating the specification and tasking of satellites, whereas historically it was dictated by Space Science and the military. As discussed in our answers to questions 14-18, it is not just the data providers that generate value, the analysis of the data and use of this analysis for applications that means there are a number of layers, each with a commercial value.

Satellite Sector Refinement

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?

The Satellite Applications Catapult believes that a single value chain to explain the satellite sector is inappropriate, as each sub-sector sector has a different value chain and different spectrum requirements. We are focussing on three key subsectors in the satellite sector:

- Communications (corresponds to broadband internet access, M2M, commercial mobility and corporate networks in Table 1)
- Navigation (GNSS) (corresponds to Navigation including location based in Table 1)
- Earth observing and remote sensing systems (Not included in Table 1, as under Space Science)

When answering the following questions we will consider Communications and Navigation. Earth observation will be considered under Space Science, to ensure we are consistent with the review process, however we would prefer to see the overarching title changed so that it reflects not only the Science side, but also the commercial value contained within the sector.

Considering each of these subsectors in turn:

- Communications: The value chain in Figure 2 works well for satellite communications services. In general a small number ‘Satellite Operators’ control the value chain up to ‘Network & Service Providers’. The three early stages of the chain are generally sub-contracted. In the UK there are a large number of ‘Distributors’ and ‘Application Providers’ reselling on the ‘Satellite Operator’ services, so although the revenues at these levels maybe significant the margins are thin. The significant margins are at the

'Satellite Operator' levels to cover their capital investment in the earlier stages of the chain.

- Navigation (GNSS): The value chain for GNSS stops at 'Satellite Operators' and restarts at 'Content or Application Providers'. There are no 'Network & Service Providers' and 'Distributors', except at the high end of navigation services when accuracy and authentication is essential. This is due to the ubiquity of GNSS signals and devices containing GNSS chips. This is highlighted by smartphones and SatNav's. The value here is in the devices and the applications that run on them, there is no direct flow back to the satellite operators as the GNSS signal is essentially free other than the receiving chip.

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.

Since its launch in May 2013 the Satellite Applications Catapult has interacted with almost 2000 organisations. These include suppliers and users of almost all the applications listed in Table 1 in Section 3. This has given us significant insights into the operation of the value chains through engagement with both the supply-side communities, as well as engagement with distributors, product, service and application developers, and end-users.

We use satellite data from all three subsectors discussed in our answer to Question 4 to offer applications directly to customers. There are many examples of applications, some of those that we are directly involved in are:

- Communications: We have worked with the Home Office to highlight the additional resilience and coverage that satellite communications can bring to the Emergency Services Mobile Communications Programme (ESMCP). The ubiquitous coverage of satellites is being used by the Highlands and Islands Enterprise to improve stroke diagnosis for remote patients. Satellites have provided seamless and ubiquitous connectivity to sensors for the remote monitoring of key transport infrastructure and we have demonstrated the value that satellite connectivity can bring to the agricultural industry to monitor crop health and provide connectivity to outlying agricultural regions not served by terrestrial communications.
- Navigation (GNSS): We are working with Ordnance Survey to understand the nature and extent of interference on GNSS. Ordnance Survey is the operator of the national GNSS infrastructure. GNSS is also an essential part of our project with the Pew Foundation to combat illegal fishing through the use of satellite received AIS data.

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.

Considering each of the Catapult's focus subsectors in turn:

- Communications: As with terrestrial mobile operators, satellite operators will have increased spectrum requirements as the number of users increases and applications require more bandwidth. To date the demand has been held back due to the high cost of satellite services, but with the arrival of higher throughput satellites, prices are expected to fall, in turn stimulating demand. Inmarsat for example currently has about 400,000 subscribers, which we would expect to increase over time. Pure satellite communication subscriber numbers are unlikely to ever reach the tens of millions level, however over time it is expected that more devices will be able to switch to a satellite signal when there is no terrestrial coverage, this could significantly increase the number of satellite capable devices, albeit that they are used infrequently. In addition, in the US there are now satellite broadband services that are capable of providing 25Mbps at price points comparable to other delivery mechanisms. This could also be an option for the UK (particularly the 5% of population that are unlikely to be reached by other mechanisms) and if so, there would be an increased spectrum requirement to provide this.

- Navigation (GNSS): The spectrum requirements in this area are relatively well defined as other than controlling the satellites it is a broadcast signal. However according to the GNSS Market Report (March 2015) there are 3.6 billion GNSS devices in use today. This means that there is a universal dependence on GNSS signals and any interference to the signal is likely to have far reaching and not necessarily predictable effects. As a result it is important that this spectrum is protected for: continued use; ensure there is no interference from encroaching commercial spectrum usage (note LightSquared in the US) and no criminal activity is permitted (such as jamming).

On moving down the value chain the number and diversity of end users increases. It is important to note that the end users of satellite enabled services are unlikely to understand the dependence of their services on the underlying spectrum. This is not dissimilar to the customers of the mobile operators, however in the case of satellite services, there is a diverse group of service providers not a handful mobile operators, which means that it is more challenging to aggregate all demands on spectrum.

All satellites require 'Telemetry, Tracking & Command (TT&C)', as the number of satellites increases over the coming years and their in-orbit capability increases, the TT&C spectrum requirement will increase. In addition as satellites are increasingly in constellations rather than solo, the need for inter-satellite links will increase again requiring spectrum.

Question 7: For each of the satellite applications you provide, please could 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).

Considering the potential UK benefit for each of the Satellite Applications Catapult focus subsectors in turn:

- Communications: According to Ofcom mobile coverage is now about 97% of the UK population, however it is only about 66% of the UK geography. This means that there are significant rural areas without terrestrial mobile coverage. In these areas satellite communications do offer an alternative and as pricing falls we would expect satellite to be an increasingly viable alternative. Similarly superfast broadband is unlikely to reach very rural areas, so fixed satellite broadband could fill the gap, ensuring that the whole of the UK has access to broadband. Satellite communications offer an additional channel which could provide resilience and redundancy for high end uses such as the emergency services. This could have a significant societal impact. According to London Economics (Case for Space 2015) Telecommunications accounts for £2 billion of the Space Economy in 2012/13.

- Navigation (GNSS): As already discussed there are 3.6 billion GNSS devices globally. The UK population is already heavily dependent on GNSS for its getting from A to B and is increasingly using location based services in daily life. According to London Economics (Case for Space 2015) Navigation accounts for £1 billion of the Space Economy in 2012/13.

- Earth observing and remote sensing systems: The general benefits are included under Space Science, however we would anticipate new services to offer new benefits as new applications are devised.

The table below is an indicative list of services that are enabled or improved through the use of satellites and the potential benefit to UK consumers and citizens:

	Nature of benefit to UK Consumers and Citizens
Land	
Broadband extension	Bridging the digital divide (last 5%) & enabling rural economies
Broadcasting	Entertainment, information services & content distribution
Health and social services	Improved timeliness and effectiveness of primary and tertiary care
Transport logistics – road	Improved and timely movement of goods and services, energy savings
Road + Rail Infrastructure	Fewer disruptions to travel with indirect economic benefits, achieved through improved monitoring of assets, maintenance logistics, traffic handling
Rail operations	Reduced travel costs through improved operational efficiency
Rail Passenger services	Improved utilisation of travel time
Agriculture/ food security	Lower cost, higher quality, and assurance of food supply. Better civilian health and associated economic growth
Forestry/ land management	Improved soils, climate change resilience, water conservation, reduced pollution, biodiversity, human health
Utilities – energy/ water/ waste operations (SCADA)	Lower consumer costs through improved infrastructure resilience, improved efficiency and productivity
Natural resources: oil & gas/ mining - exploration	Lower costs and better performance of goods – enabled by more effective location of metal and mineral deposits
Natural resources: extraction/ management	Lower costs and better performance of goods – enabled by more effective extraction of metal and mineral deposits
Manufacturing supply chain & distribution	Lower costs and more personalised choice of goods enabled by productivity enhancements in supply chains
Retail Point of sale (inc fuel)	Lower costs through higher productivity, assurance of supply, reduced commercial friction and reduction of fraud
Finance/ Banking/ Insurance	Improved services, improved access to finance, reduced costs for export and

	import, reduced commercial friction
Cellular Backhaul	Improved service coverage and reach, closing of digital divide, support for e-commerce in local economies, improved resilience of infrastructure for safety and health
Newsgathering	Better informed populace, improved social dynamics, reduction in international prejudice
Film/ media production/ arts	Improved economy through employment, wellbeing, and wealth, cultural impact and improvement in social values
Education	Improved educational services across the digital divide
Maritime	
Fishing	Indirect benefits to consumers. Preservation of fish-stocks and assurance of supply. Protection of UK national interests.
Freight logistics	Direct benefits to consumers – higher efficiency for movement of goods – reduction in cost of transport and delivery charges
Safety Services	Direct benefits to mariners. UK coastguard and RNLI dependency.
Fleet management, Vessel Efficiency	Direct benefits to operators, consumers and import/ export activities.
Cruise (Vessels)	Direct benefits to cruise operators and vacationers
Leisure vessels	Direct benefits to users and support of supply chain
Offshore renewables	Independence and resilience of energy supply
Offshore Oil & gas	Ensuring that UK oil and gas organisations maintain presence
Aviation	
Aviation safety	Improved assurance of safety in air travel
Airline operations	Improved airline efficiency, reduced delays in journey time, savings in energy
Passenger communications	More effective use of travel time
Freight	Improved logistics and tracking of goods
Helicopters operations	Improved efficiency
Government	
Local government services	Better services to citizens, higher efficiency in local gov.
Environment management	Better environment, high efficiency in central gov.
Border security	Reduction in crime, higher tax revenues
Disaster/ incident response	Effective blue-light services, protection of citizen
Defence	Reduced impact of terrorism on society, secured resource

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

The Satellite Applications Catapult believes that there are three key high level trends that will affect the satellite sector in the coming years:

- Increased affordability of satellite communications services: This will be a combination of the increased availability of higher throughput satellites and lower equipment costs. This will make satellites a viable option where terrestrial coverage is not present and also to provide redundancy and resilience for higher end applications.
- Lower cost access to space: This will enable a range of smaller satellites to be added to the existing ones which will offer new opportunities and markets. We are just at the start of this process with companies such as PlanetLabs and Skybox Imaging leading the way.
- Increasing accessibility of EO data: This will result in a wide range of new applications being developed. These are just starting now, but as the data becomes available through the Copernicus programme and new data pricing models are introduced we would expect a significant uptake in this area.

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).

Considering each of the Satellite Applications Catapult focus subsectors in turn:

- Communications: The arrival of high throughput satellites will lower the price point of satellite services. This in turn will allow a step change in the uptake of satellite services, both to provide coverage where there is no terrestrial coverage as well as redundancy and resilience. In addition, fixed satellite broadband could become a viable alternative to fibre, as it is in the US, providing satellite capacity is increased and spectrum is available.

- Navigation (GNSS): The proliferation of smart phone and other devices that are GNSS capable with new location based services (such as location specific advertising and location based gaming) will increase the usage of GNSS signals. However as mentioned this is unlikely to directly affect the demand for spectrum as it is a broadcast signal. However this increased use and dependence for critical services is also likely to increase the potential for criminal activity with the aim of disrupting these signals. This in turn could increase the need for more secure GNSS which in turn is likely to have spectrum demands. The arrival of Galileo and its increased functionality over the next five years will also offer new and innovative commercial opportunities for the sector.

In our view it is more important to create a flexible regime that will enable, support and encourage experimentation with different orbits, frequencies and enable successful technologies to emerge and thrive on an international scale. Being too prescriptive based on current and predicted future trends risks limiting the UK's potential to capitalise on the opportunities that these innovations present.

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.

The Satellite Applications Catapult sees two key challenges for the future:

- Ensure sufficient capacity for future users: For example, if satellite broadband access is used more widely for redundancy and resilience, as well as becoming a viable alternative to fibre for areas less well served for broadband access, it will require additional satellite capacity over the UK, which in turn will need additional spectrum. The high cost of putting a satellite in place means that additional spectrum costs (if competed) may preclude this as a viable option, which could be to the detriment of the UK economy.

- The satellite sector is going through a dramatic change with the arrival of lower cost, small satellites, many built in the UK. These will enable new business models to be created, many of which are not known today. This makes predicting future spectrum requirements challenging.

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?

The list of potential mechanisms identified within the consultation report are appropriate. Improvement to antenna beam focussing techniques can be undertaken on a single spacecraft using deployable structures, however the technology for such capability is still at a relatively early stage of maturity (compared with that which could be achieved). This technology requires that the on-board processing, feeder-link technologies and ground-system architectures are all evolved simultaneously. It is likely that for single-spacecraft systems, the technology will allow a one-order of magnitude improvement in the next 10 years.

With regard to transmitter, receiver, and waveform technologies, these have reached a high level of maturity. For mass-market adoption, the technologies should be shared with terrestrial systems to reach economies of scale. It is increasingly likely that the integration into software-radio platforms will be practical even at consumer level. Filtering out unwanted signals can be achieved with increased complexity, subject to either improved a-priori knowledge of the interfering signals, and the effective performance of the analogue elements of the receivers. Compression techniques are relatively mature and have limited impact on spectrum utilisation.

Mechanisms for interoperability between satellite systems, and between satellite and terrestrial systems will need to be developed more completely for both cooperative/ predictive and measurement/ responsive approaches. Use of white-space technologies in terrestrial systems could enhance the viability of ad-hoc sharing of spectrum, conditional on the appropriate standards and regulatory frameworks being established and enforced. Such technologies could enhance the available bandwidth for both satellite and terrestrial wireless systems by 0.5-1 orders of magnitude, with a step-change in institutional investment for systems to enforce the behaviours associated with spectrum sharing.

Changes to satellite parameters to reduce requirements for orbital separation are interesting, however the trends (driven by user demand) for satellite terminals is towards smaller devices that have less sidelobe control, operating in environments that are more highly cluttered. This tends to increase the level of interference into competing satellite systems, and as this is noise-like and unresolvable it is unlikely that simply changing power flux density constraints will improve the situation from the perspective of spectrum reuse.

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?

To achieve maximum exploitation of the spectrum a number of technological innovations will be necessary. The first relates to the ability to deploy interference mitigation measures in the space segment itself. This will require more complex satellite system architectures, using spatial diversity techniques, together with dynamic filtering and real-time beam reconfiguration, ground-based beamformers using cloud-based architectures. Mechanisms for supporting ultra-wideband feeder links, such as TeraHertz and optical frequencies, together with significant investments in ground-based technologies and system architectures. Such mechanisms could introduce a 2.5 to 3 order of magnitude improvement in satellite system capacities with a 1 order increase in investment. The challenge for such changes is the diverse nature of the opportunities and the need to develop the new distribution networks and associated value chains to secure the investment in the 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.

The Satellite Applications Catapult has not identified any additional regulatory action, although would like to see the UK as an active participant in all European and International spectrum discussions to ensure that the UK's leading position in the commercialisation of satellite enabled services can be capitalised on.

Space science respondents

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?

As discussed in Question 3, the Satellite Applications Catapult believes that there are two elements to space science: a science focussed side and a commercial side. We are concentrating our efforts on exploiting the commercial opportunities for using Earth observation (EO) and remote sensing systems. As a result our answers will concentrate on this element, we would anticipate other institutions including universities and organisations, such as the Met Office, to comment on the science focussed side.

The value chain for Earth Observing and remote sensing systems can be represented by Figure 2, however it needs to be noted that historically institutions and space agencies have occupied the value chain up until 'Satellite Operators'. This is changing and commercial operators are increasingly part or completely owning the satellites (often with committed Governments contracts). From 'Network & Service Providers' onwards the value chain is very complicated and multi-layered. Increasingly commercial providers are using the information and dictating the amount and type of data acquired. Historically this was done either by institutions focussed on Space Science (or the military). EO data has historically been designed for academic or EO expert purposes, so is complicated to process and use. This has created the opportunity for 'Content Providers' to take the complex array of data and process it into packages that can be readily used, this in turn is resulting in a wealth of new applications (the uptake of Google Earth type applications is an example of this).

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.

The Satellite Applications Catapult has relationships with a wide variety of satellite applications providers. This has given us significant insights into the operation of the value chains through engagement with both the supply-side communities, as well as engagement with distributors, product, service and application developers, and end-users.

In addition we directly provide a number of services based on Earth observation data. For example, we are providing Milton Keynes Council with a planning tool, which uses multiples sources of satellite imagery to identify unauthorised building and to confirm progress of planned developments. The application creates changes layers using both optical and SAR missions. Another example is our project with the Pew Foundation to combat illegal fishing through the use of satellite received AIS data, which, like the planning tool, relies on EO radar and optical data to monitor activity when the AIS systems are switched off (which is typical when illegal activity is taking place).

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.

The Satellite Applications Catapult believes that spectrum requirements within space science can largely be considered in three specific segments:

- Satellite control
- Download/downlink of acquired data
- Active remote sensing systems, for example radar

Considering these in turn:

- Satellite control: This is a fairly limited spectrum requirement, however with the increasing number of satellites, particularly large constellations of small satellites, the requirement here will grow.
- Download of data: Current satellites download data when in sight of a ground station. With new satellites such as the Sentinels there will be an increased amount of data requiring more regular download, this in turn will require greater bandwidth. As there will be more satellites there will be an almost constant (rather than intermittent) download of data. The EO21 report ‘EO Market Trends’ (http://www.eo21.org/wp-content/uploads/2015/03/EO21-Indicator-of-Trends.pdf) notes that commercial EO satellites were collecting more than 4 million square kilometres of imagery every day in 2013 and the ESA spacecraft alone will obtain 25 petabytes of EO data from the full Sentinel constellation as part of the Copernicus programme.
- Active systems: In simple terms the wider range of frequencies that EO satellites can operate at, the more enriched the overall picture and hence information that can be drawn from it. Different wavelengths are required to study different characteristics, for example the longer the wavelength the greater the level of penetration through

certain surface features such as vegetation and arid substrates. An example of this includes using longer wavelengths, such as L and P band microwaves to study tree structure and biomass, whereas for the identification of leaves shorter wavelengths are required. There are already limitations for EO satellites due to spectrum having other uses, for example long wavelength radar penetrates through rainforests to study biomass clashes with anti-missile frequencies, so can only operate in some areas, an example mission is ALOS with the PALSAR L band Synthetic Aperture Radar Payload.

- In addition, for monitoring purposes radar is essential. Radar instruments observe important and unique information on the structure and textural information about the Earth's surface. Furthermore using the phase information it is possible to identify very subtle change in coherence and land deformation. Using techniques such Persistent Scattering Interferometric Synthetic Aperture Radar (PSInSAR) it possible to observe millimetric movement of coherent structures in the line of sight of the satellites, this is particular important for monitoring critical national infrastructure.
- Radar systems have a couple of important advantages over their optical counterparts. Cloud coverage is a big problem for optical remote sensing, especially in mid latitude countries such as the UK, due to the longer wavelengths in the microwave portion of the electromagnetic spectrum the sensors are able to penetrate through water vapour. Another advantage is that radar systems have a diurnal capacity whereby they can image day and night as they are solar independent.
- C-band radar is used by a range of commercial operators and there is more than 25 years of observations using this frequency band. C-band applications are very diverse, examples include both commercial and public/academic applications: contributing to climate change records, agricultural monitoring, ground deformation measurements, oil spill identification, land cover classification including urban development and flood mapping among many others. The largest user of radar remote sensing technologies is the military. Currently the commercial industry is limited, but is the area we see the greatest potential for future growth, providing the spectrum is available to continue existing datasets and complement with new ones. Recent and ongoing investment by the EU member states, including a significant investment by the UK in the Copernicus programme, for example the Sentinel-1 C-band SAR mission showing the EU's commitment to sustain these observations. This "flood" of freely available and operational C-band data will significantly increase the commercial service market size.

All satellites require 'Telemetry, Tracking & Command (TT&C)', as the number of satellites increases over the coming years and their in-orbit capability increases, the TT&C spectrum requirement will increase. In addition as satellites are increasingly in constellations rather than solo, the need for inter-satellite links will increase again requiring spectrum.

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).

One of the roles of the Satellite Applications Catapult is to increase awareness of the benefits of space enabled applications. By increasing this awareness and combining with new and existing terrestrial technologies into the space sector, such as the Internet of Things and cognitive computing, we expect to see new and innovative applications being created. Aside from demonstrating the potential we are also working on projects that will deliver commercial services in the future. There is a wide range of potential commercial applications using EO data for example: insurance assessments, commodity markets, agriculture, oil and mining, utilities and environmental impact assessments. Combining satellite data with additional sources such as UAVs and in situ remote sensors will enable a new range of services to be developed.

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

Within the EO industry the demand, until recently, from the military sector has always over shadowed that from other sectors; with the sector accounting for 2/3 of the data market. Continual market pull for higher spatial resolution satellites, along with legislation changes to grant the sale of up to 0.25m imagery in the USA by February 2015, has meant that there has been a decrease in the gap between military and commercial EO satellite capabilities.

Furthermore with the advent of increasingly open access data and software sources (such as the Sentinel Satellites from the EC and ESA Copernicus Programme and their associated toolboxes) there has been a noticeable growth in application development external to that of the military. Infrastructure and energy monitoring, including future cities activities, is really driving the need for continued growth in high quality commercial and open EO datasets to fuel the underlying mass markets.

External to the physical space assets and their associated data there are two major areas of demand. The first is around the need for real time or near real time services, such as the envisaged service from EDRS or on board satellite processing. Secondly the trend to fuse terrestrial and spaceborne (optical and increasingly radar) data from a network of sensors, pulling on technologies such as Internet of Things and Linked Data, is growing year on year. These identified major trends are lowering the threshold into the sector and making the technology increasingly relevant to the general public. This is turning the EO industry from one which is dominated by academics and highly skilled professionals to one which can reach a mass market.

Euroconsult in 2012 highlighted that the EO commercial data in 2011 was US$1.4 billion and that the number of EO satellites will almost double over ten years to 288 in 2021.

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 Satellite Applications Catapult believes that the increased data that can be acquired by the satellites, especially with the emergence of large small satellite LEO constellations, will increase the demand for bandwidth to transmit it to the ground on a regular basis to allow high quality and near real time provision of satellite images and data. Most satellite operators are looking to a global network of ground stations to allow almost constant download of the satellite data. With satellite constellations there will be almost constant visibility of a satellite for each ground station, making the download continuous where it is currently intermittent. This in turn will have global spectrum requirements to ensure global consistency. It is essential that the UK is able to download data so that it is able to develop applications using the continuous data.

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.

At this stage the key challenge is stimulating the interest to develop applications. The data received directly from the satellites requires skilled EO experts to analyse it and turn it into more readily accessible products. Getting this chain in place when the end user applications are still being finalised is challenging, but offers a significant first mover advantage to the UK if it is able to get these systems in place.

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 additional comments.

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?

No additional comments.

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 additional comments.

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.

No additional comments.