Introduction

Transfinite is pleased to provide Ofcom with this response to the call for inputs (CFI):

- *Call for Input: Strategic review of satellite and space science use of spectrum, Ofcom 4th June 2015*

This response provides Ofcom with information regarding the European Commission's interests in UK satellite and space science spectrum via the Galileo/EGNOS and Copernicus space programmes.

This document includes background information on these programmes and answers to each of the questions raised by Ofcom.

We would be happy to provide further information on request to clarify any points in this response. In addition, we would be grateful to be kept informed of any workshops or further developments within this strategic review.

Background

The European Commission is responsible for the development of three major satellite programmes that use parts of the radio spectrum covered by this CFI. In particular:

- **Galileo** is the European satellite navigation system operating under the ITU's radionavigation satellite service (RNSS)
- **EGNOS** is the European space-based augmentation for the US Global Positioning System, also operating under the RNSS allocation
- **Copernicus** is a European system to monitor the Earth operating under the ITU's Earth exploration satellite service (EESS) both active and passive. The core of the project are the **Sentinel** satellites, though there are addition payloads on other satellites (e.g. Jason).

In addition, both operate TT&C links under the space operations service and there are mobile satellite service payloads on Galileo satellites providing search and rescue services.

The UK is a major supporter of both programmes via the UK Space Agency (UKSA) and other groups such as the UK Space Satellite Navigation Committee. The UK is involved in the development, operation and application of both programmes through resources such as Surrey Satellite Technology Ltd and the Harwell Satellite Applications Catapult.

These projects are described in more detail in the Sections below and further information is available at:

http://www.gsa.europa.eu/galileo/why-galileo

http://www.copernicus.eu/main/overview

Following sections provide answers to each of the questions posed by Ofcom. For the sake of this CFI, the questions have been answered assuming:

- Galileo and EGNOS are defined as satellite applications
- Copernicus is defined as a space science application

Copernicus Overview and Applications

Overview

Copernicus is a European system for monitoring the Earth. It consists of a complex set of systems which collect data from multiple sources: earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors. It processes these data and provides users with reliable and up-to-date information through a set of services related to environmental and security issues.

The services address six thematic areas: land, marine, atmosphere, climate change, emergency management and security. They support a wide range of applications, including environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism.

The main users of Copernicus services are policymakers and public authorities who need the information to develop environmental legislation and policies or to take critical decisions in the event of an emergency, such as a natural disaster or a humanitarian crisis.

Based on the Copernicus services and on the data collected through the Sentinels and the contributing missions, many value-added services can be tailored to specific public or commercial needs, resulting in new business opportunities. In fact, several economic studies have already demonstrated a huge potential for job creation, innovation and growth.

The Copernicus programme is coordinated and managed by the European Commission. The development of the observation infrastructure is performed under the aegis of the European Space Agency for the space component and of the European Environment Agency and the Member States for the in situ component.

Copernicus is designed to be a global system, but the UK benefits from the system in each of the sectors described below, either directly or by providing evidence to assist policy making.

Agriculture, Forestry and Fisheries

In the domain of agriculture, EU policies aim to foster the development of practices that preserve the environment and sustain productivity.

Copernicus helps to assess agricultural land use and trends and their impacts on biodiversity and landscapes. Copernicus can also help assess crop conditions and yield forecasts. Additionally, it can help public authorities and farmers improve irrigation management by monitoring agricultural pressure on water.

In the domain of forestry, Copernicus provides solutions to identify forest types, detect changes, map and monitor clear-cuts and assess forest density and health. This can in particular support users in their reporting obligations towards national and international policies (e.g. UN Framework Convention on Climate Change).

Copernicus also contributes to the sustainable management of living marine resources. Thanks to its ability to monitor phytoplankton, algae, pollutants, water temperature, etc., Copernicus can support efficient fishing operations, water pollution detection or help to identify the most favourable areas for installing fish farms.

Biodiversity and Environmental Protection

Monitoring the environment in order to support its protection and sustainable use is the main "raison d'être" of Copernicus. It permanently monitors land, atmosphere and oceans and provides timely and accurate information on the state of our planet.

As far as land is concerned, Copernicus provides information on land use, soil moisture, vegetation state including forests, water quality and quantity for both rivers and lakes, snow cover, land carbon, etc.

This information can in turn be used to support applications in many different domains including spatial planning (e.g. urban growth monitoring), water management (lake/reservoir depths and levels), forest management (e.g. crown cover density monitoring), protected area management (e.g. Natura 2000 site monitoring) and biodiversity (e.g. habitat monitoring), which all play a key role in environmental protection.

In the domain of marine monitoring, Copernicus provides information on parameters that characterise the state of our oceans and regional seas, such as temperature, salinity, currents, ice extent, sea level and primary ecosystems.

This information supports a wide range of applications in domains related to the protection of the marine environment such as marine resources management (e.g. fish stock management), climate and seasonal forecasting (e.g. ice seasonal forecasting) and marine and coastal environment (e.g. water quality monitoring).

The Copernicus atmosphere monitoring service completes the picture by providing information on key constituents such as greenhouse gases, reactive gases, ozone and aerosols.

This continuous monitoring and forecasting of the composition of the atmosphere enables in particular to assess pollution levels, which also have an impact on the environment.

Civil Protection and Humanitarian Aid

Every year, hundreds of millions of people are directly affected by natural disasters (such as, volcanic eruptions, earthquakes, fires, storms and floods), technical accidents (like oil spills) and humanitarian crises. In Europe for instance, southern countries are regularly facing major wild fires whereas central Europe is often affected by severe flooding episodes.

Copernicus supports public authorities in all the phases of disaster management. Copernicus can support preparedness and prevention by providing data that helps to identify risks and prevent loss of lives and damages.

During the response phase, Copernicus supports civil protection operations by providing products like maps identifying the extent of the disaster (e.g. delineation of the flooded area) and the level of damage (e.g. destroyed buildings in case of an earthquake).

During the recovery phase, Copernicus can help to monitor the medium- and long-term impacts on environment, human safety and economy, and their evolution.

Climate and Energy

The international community agrees that human reliance on burning fossil fuels for energy is considered to be one of the causes of global climate change, and on the other hand, we face a looming energy crisis as the threat of peak oil approaches.

By 2020, at least 20% of the energy supply in the EU should stem from renewable sources. Wind, a proven source of clean, affordable energy, will play a key role in reaching this binding target. The sun is also an amazing source of sustainable renewable energy: Deserts get more energy from the sun in one day than mankind consumes in one year.

Copernicus can support the efficient exploitation of these renewable energies, which will help to meet the growing global energy demands without increasing CO2 emissions.

For instance, the Copernicus Marine Environment Monitoring Service provides information relevant to offshore wind farms, such as wind speed, wind fields and wave size and frequency. These parameters are crucial in determining where wind energy can be generated in the most cost-effective way whilst reducing the risks of damage.

Another example is the Copernicus Atmosphere Monitoring Service, which monitors the atmospheric conditions having an impact on the solar radiations that reach the Earth surface and provides the solar energy sector and public authorities with suitable and accurate information for a better management of solar energy.

Public Health

Air pollution is a critical factor affecting the health of EU citizens. Every year, several hundreds of thousands of premature deaths can be attributed to fine particles present in the air we breathe.

'Air pollution is bad for our health. It reduces human life expectancy by more than eight months on average and by more than two years in the most polluted cities and regions. Member States must comply with EU air quality standards quickly and reduce air pollutant emissions', Janez Potočnik, EU Commissioner for the Environment.

Similarly, it is estimated that overexposure to UV radiation is a major cause of skin cancers, which increase by 5 to 7% every year in Europe.

Copernicus contributes to UV forecasts that enable people to adjust their behaviour according to their personal situation.

Tourism

Thanks to its capacity to monitor the environment, Copernicus can support applications in the domain of tourism.

The main domain of application concerns the assessment of bathing conditions. For instance, the Copernicus marine environment monitoring service can be used to implement coastal water quality services that can in turn help public authorities to enhance protection of bathing waters.

The service can also help to detect jelly fish populations and predict algal blooms.

Transport and Safety

Transport represents an important sector of the economy, and ensuring passenger safety is a priority for carriers, governments and local authorities.

The development of road transport networks brings significant benefits to citizens but often has negative effects on the environment (e.g. increase of air pollution, noise and soil sealing levels). Reducing these negative impacts generally requires that public authorities take appropriate regulating measures (e.g. reduce speed limits in case of pollution peaks). Thanks to its ability to monitor air pollution, Copernicus can support public authorities in implementing such measures.

In the case of maritime transport, the information on currents provided by Copernicus can support ship routing services. Information on sea ice can contribute to improve navigation safety significantly in Arctic regions.

As far as infrastructures are concerned, Copernicus can support their protection by identifying the areas exposed to a subsidence risk and detect ground movements likely to destabilise buildings, bridges, roads, etc.

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Galileo Overview and Applications

Overview

Galileo is the European global satellite-based navigation system

Until now, radionavigation satellite service (RNSS) users around the world have had to depend on American GPS or Russian Glonass signals. Galileo gives users a new and reliable alternative, run by civil, not military authorities.

Satellite positioning is now an essential tool for all forms of transportation; if RNSS signals were switched off tomorrow, truck and taxi drivers, ship and aircraft crews, and millions of average citizens around the world would be lost – literally.

As the use of satellite-based navigation systems continues to expand, the implications of potential signal failure become even greater. Such an event, whether accidental or intentional, would jeopardise financial and communications activities, public utilities, security and humanitarian operations and emergency services.

As far back as the early 1990s, the European Union saw the need for a European-controlled global satellite navigation system. The decision to build one was taken in the spirit of other well-known European endeavours, such as the Ariane launcher and Airbus.

A defining characteristic of Galileo is that, unlike GPS and Glonass, it was conceived and developed and will always remain under civilian control.

While European independence has been a key goal behind the creation of the new system, Galileo is nevertheless 100% interoperable with GPS and Glonass, making it a fully integrated new element in the worldwide global navigation satellite system, a powerful cornerstone that will allow more accurate and more reliable positioning, even in high-rise cities where buildings can obscure signals.

GPS, and to some extent Glonass, have opened up the markets for accurate positioning and timing, Galileo will take that further by working interoperably with GPS (and other RNSS systems) to offer even more reliable positioning, navigation and timing (PNT). This increased reliability and availability in areas such as city centres with tall buildings is likely to open up a range of new business opportunities for equipment manufacturers, application developers and providers of ‘reliability-critical' services.

Galileo also intends to offer signal authentication to its users to counter the growing threat of RNSS spoofing. This is a unique feature of Galileo compared to any other satellite navigation system and will enable Galileo to be used where verified positioning or timing is required. This full authentication will be offered using the so called “Commercial Service”, but a basic level of authentication is being considered for the free to access “Open Service” signals.

Improved emergency and rescue services

Global Navigation Satellite Systems such as Galileo allow users worldwide to pinpoint their locations or the locations of other people or objects at any given moment.

A simple concept, perhaps, but the range of possible uses for this sort of capability is enormous, spanning many domains, both public and private. Numerous potential applications have already been identified, based on the quality and reliability of Galileo signals, but the list is certain to grow, limited only by the imaginations of innovative entrepreneurs and service providers.

Location-based services

The integration of accurate positioning signal receivers within mobile telephones, personal digital assistants (PDAs), mp3 players, portable computers, cameras and video devices, will bring Galileo services directly to individuals, making possible a fundamental transformation of the way we live and work.

Location Based Services (LBS), identified as the main initial market for Galileo, include a broad range of applications such as ‘Mobile Yellow Pages' or ‘Proximity Services', providing users, wherever they are, with information and advertising about nearby businesses and services.

Dedicated positioning devices will be available for tourists or hikers, for amusement park and museum visitors, and people within large shopping centres.

Emergency, security and humanitarian services

Galileo-ready devices will enable new security-related applications, permitting the location of stolen property, for example, or lost pets or individuals.

Galileo signals facilitate civil protection operations in harsh environments, speed up rescue operations for people in distress, and provide tools for coastguards and border control authorities.

Galileo's Search and Rescue (SAR) function is linked to the operational Cospas-Sarsat system, wherein satellites are equipped with transponders that can transfer distress signals from user distress beacons to a rescue coordination centre. Galileo satellites also have the capacity to return a message back to the distress beacons to indicate that the distress signal has been received by the rescue centre.

Science, environment, weather

Galileo services will be used to carry out scientific research in meteorology and geology, in the field of geodesy, to track pollutants, dangerous goods and icebergs, to map the oceans, study tides, currents and sea levels.

Galileo will allow improved monitoring of the atmosphere, of water vapour for weather forecasting and climate studies, and the ionosphere for radio communications, space science and earthquake prediction. It will also help to better understand the movements of populations of wild animals.

The scientific community will benefit from high-accuracy Galileo timing signals (see below), allowing precise adherence to international time standards and calibration of atomic clocks.

Transport

Satellite navigation can increase traffic safety and efficiency by improving the way we use vehicles. Highly accurate and reliable Galileo signals will serve fleet management, enabling the delivery of detailed maps or voice notifications to locate specific shipments and containers in road transport. It will deliver similar benefits in aviation, maritime and rail transport, and even for pedestrian traffic.

Agriculture

By integrating Galileo signals with other technologies, the agriculture community can benefit from improved monitoring of the distribution and dilution of chemicals, improved parcel yield thanks to customised treatment and more efficient property management.

Fisheries

The fishing industry will see more effective information exchange between vessels and stations and improved navigation aids for fishermen.

Civil Engineering

Accuracy and reliability are absolute requirements in civil engineering. Combined with digital mapping, Galileo offers a powerful tool for decreasing cost and increasing productivity while maintaining the highest construction standards, from the planning of structures to the maintenance and surveillance of existing infrastructure.

A crucial time reference function

Galileo satellites are synchronised to an extraordinary level of accuracy with the widely used Universal Time Coordinate (UTC) time scale. Thus, Galileo is capable of delivering a critical timing signal useful in many areas of application.

Communications

Wireless telecommunication networks will use this timing signal for network management, for time tagging and for synchronisation of frequency references.

Finance, banking, insurance

Galileo's extremely accurate clock makes it a formidable instrument for authentication and ‘time stamping' of financial transactions. In today's information society, security, data integrity, authenticity and confidentiality have emerged as major issues in the exchange of electronic documents and computer files. Certified time stamps are necessary for applications such as electronic banking, e-commerce, stock transactions, quality assurance systems and services. Galileo will play a key role in the protection of such information, using the latest authentication techniques.

Energy

Accurate location systems are indispensable in the design, construction and operation of modern energy networks. Power grids must be continuously monitored, and when a power line breaks or a failure occurs, it is vital that monitoring instruments are synchronised with maximum accuracy. The high-quality of time synchronisation represented by Galileo will mean better services for energy transport and distribution.

Similarly, in the oil and gas sector, marine seismic exploration will increasingly profit from Galileo services to seismic acquisition vessels and seismic streamer arrays and gun arrays. High-resolution surveys of new sites and identification of any geomorphologic or geophysical risks will also increase the safety of drilling activities.

As already stated, the list of possible applications is still to be completed and the full potential for user services and devices unknown. It will be noted that GPS-based services already exist in many of the areas mentioned above. The key point is that Galileo will increase the levels of accuracy and reliability, making possible a new range of more beneficial and commercially profitable products and services.

EGNOS Overview and Applications

Overview

EGNOS is the European space-based augmentation for the US Global Positioning System and is a joint project of ESA, the European Commission and Eurocontrol (the European Organisation for the Safety of Air Navigation).

EGNOS provides enhancements to the GPS service by providing regional signal corrections aiding increased accuracy. More importantly it also provides integrity data used for safety-of-life applications especially, but not exclusively, in the aviation sector.

Using a network of reference ground stations that collectively monitor and analyse GPS (and in future Galileo) signal quality, EGNOS transmits the relevant data to users via GPS-like signals transmitted from at least two geostationary satellites.

EGNOS is primarily used in the aviation sector, where it is certified under rules and regulations set by the International Civil Aviation Organization (ICAO), but it is also used, or expected to be used, in the marine, rail and road sectors as well as in agriculture. The UK was one of the first countries in the EU to benefit from EGNOS deployment as many precision approaches enabled by EGNOS have been defined for UK airports.

EGNOS has been in operation since 1 October 2009, with safety of life services declared available for aviation on 02 March 2011.

Response to CFI Questions

All respondents

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

Response:

Scope of Ofcom's Duties

The description of Ofcom's approach in Section 2 of the CFI did not reference the full range of Ofcom duties under the Communications Act. In particular, the focus in Section 2.7 was on the benefits to UK citizens and consumers, described in the Act under "*3 General Duties of Ofcom*".

There should also be reference to "*4 Duties for the purpose of fulfilling Community obligations*". This section references the Framework Directive:

> *Directive 2002/21/EC Of The European Parliament And Of The Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive)*

Legislation at the EU level is not constant and has been developed further since the Framework Directive, as was originally envisaged, such as:

> *In accordance with Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive), the Commission may submit legislative proposals to the European Parliament and the Council for establishing multiannual radio spectrum policy programmes.*

In particular, Decision No 243/2012/EU of The European Parliament and of the Council of 14 March 2012 established a multiannual radio spectrum policy programme which includes:

Article 8

Spectrum needs for other specific Union policies

1. Member States and the Commission shall ensure spectrum availability and protect the radio frequencies necessary for monitoring the Earth's atmosphere and surface, allowing the development and exploitation of space applications and improving transport systems, in particular for the global civil navigation satellite system established under the Galileo programme (1), for the European Earth monitoring programme (GMES) (2), and for intelligent transport safety and transport management systems.

Therefore, there are obligations on Ofcom under the Communications Act and European legislation to "*ensure spectrum availability and protect the radio frequencies"* used by the Galileo and GMES (i.e. Sentinel / Copernicus) satellite systems.

It is also noted that under "*5 Directions in respect of networks and spectrum functions*" the Secretary of State can direct Ofcom for one of the following purposes:

(a) in the interests of national security;

(b) in the interests of relations with the government of a country or territory outside the United Kingdom;

(c) for the purpose of securing compliance with international obligations of the United Kingdom;

There are elements of the Galileo programme, namely the "Public Regulated Service", that are intended for governmental use and have security implications, with additional political implications involving other governments and obligations (e.g. under EU legislation). The UK is a prime driver for these security aspects and works collectively with other EU Member States to realise the security requirements for the system, which includes spectrum use.

Concept of Value

For the Galileo and Copernicus programmes it is hard to quantify value as:

- There is a lack of visibility (either if not known or commercially sensitive) of end uses. The Copernicus programme has adopted a free, full and open data policy available to all users for the Sentinel data products via a registration process. Similarly Galileo receivers are not registered and their use and applications will not be known to the satellite operator.
- There are non-commercial benefits, such as public safety, political independence, security benefits
- The products are involvement in multiple value chains – all the applications mentioned use navigation services plus many others not listed
- Global scope: both projects have global applications which, in an interconnected world, could have unexpected UK benefits. For example, a Copernicus remote sensing image could be used in an overseas construction project with UK contractors.

In particular, it is understood that the majority of the value occurs in the final part of the value chain, that involving end users. However that community is unlikely to be responding to this CFI. Therefore, this response will include those users and applications that we are aware of.

There has been recent discussion by economists about the issue of value in relation to the "productivity gap" question. Whereas information technology has transformed many industries, there has not been a corresponding increase in economic activity.

However it has been suggested by microeconomics professor Hal Varian that this is due to a failure of measurement. The example given[1] was:

> *when we use Google Maps to navigate round an unfamiliar city, nothing appears in GDP. Google knows where we are to within a few yards, which feels slightly spooky, but the fact that we have not had to buy a map, or even subscribe to satnav, does not appear in GDP.*

This is of particular relevance to this response as it gives examples of both remote sensing and radionavigation services.

In this case there is significant public benefit even if there have been no commercial transactions. This benefit can be judged by considering the two cases:

1. The user would have previously paid for these services (e.g. by purchasing a map). In this case there was effectively an increase in disposable income for that user, a transfer of value from the map provider to the customer
2. The user would not previously have paid for these services, and hence would not have had access to mapping services. In this case there is access to the mapping service that would have otherwise been denied.

In both cases there was value benefits to the user but neither would have been quantified as part of GDP.

Satellite respondents

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)?

Response:

As described in the Galileo overview, an important application of RNSS is providing time synchronisation services and this wasn't included in the CFI list of applications.

Note that all the end-user applications listed (and many others) would use RNSS services, and at most parts of their value chains.

In addition, the Galileo system includes navigation, positioning and timing, as well as emergency distress alert services.

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?

Response:

RNSS differs from (say) TV services where the value chain has a clear end user. In particular:

- RNSS is used by all the applications identified in this CFI and also many others
- RNSS is a resources that is used near ubiquitously both geographically and between sectors
- RNSS is free to use and hence there is less information directly available about benefits

[1] http://www.independent.co.uk/news/business/comment/hamish-mcrae/productivity-isnt-the-problem-after-all--its-the-way-wemeasure-it-10409052.html

- RNSS is the input to many other value chains from gaming to mapping to aeronautical and maritime services

The complexity of measuring the value of Galileo and EGNOS was mentioned in the initial comments under Question 1 and is discussed further in the response to Question 7. Work referenced in this section suggests that the vast majority of the value is in the end user community.

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.

Response:

This response provides information on the European Commission's activities, in particular for this question, those relating to Galileo and EGNOS. These include the following end-user applications:

- Navigation and positioning
- Time synchronisation
- Emergency distress alert.

In addition, the satellite network uses TT&C under the space operations service.

The involvement in the value chain for these applications are as:

- Satellite operator
- Network & service providers
- An example of an end user.

It is unlikely that the vast majority of end users are unaware of this CFI and would not respond (or even be aware that their activities are covered by this CFI). However these end users represent the majority of the value involved.

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.

Response:

The Galileo network is under construction and will have the following characteristics:

- 30 in-orbit spacecraft (24, plus 6 active spares)
- Orbital altitude: 23,222 km (MEO)
- 3 orbital planes, 56° inclination, ascending nodes separated by 120° longitude (8 operational satellites and two active spares per orbital plane)
- Satellite lifetime: >12 years

The main frequency bands and relevant services for which Galileo have filed are as given in the table below.

Band (MHz)	Service
406 - 406.1	MOBILE-SATELLITE (Earth-to-space)
1164 - 1300	RADIONAVIGATION-SATELLITE (space-to-Earth) (space-space)
1300 - 1350	RADIONAVIGATION-SATELLITE (Earth-to-space)
1559 - 1610	RADIONAVIGATION-SATELLITE (space-to-Earth) (space-space)
2025 - 2110	SPACE OPERATION (Earth-to-space) (space-to-space)
2200 - 2290	SPACE OPERATION (space-to-Earth) (space-to-space)
2483.5 - 2500	RADIODETERMINATION-SATELLITE (space-to-Earth)
5000 - 5010	RADIONAVIGATION-SATELLITE (Earth-to-space)
5010 - 5030	RADIONAVIGATION-SATELLITE (space-to-Earth) (space-space)

The Earth station locations are given in the table below:

Location	Latitude	Longitude
Kiruna, Sweden	67.86N	20.97E
Kourou, French Guiana	05.08N	52.63W
Reunion, Indian Ocean	21.22S	55.57E
Noumea, W Pacific Ocean	22.27S	166.41E
Papeete, Tahiti	17.58S	149.62W

The service will be global and the user community is estimated to be potentially billions, noting that the system is not fully deployed and spectrum requirements do not scale with number of users. The user community in the UK is expected to be almost all citizens (and hence in the tens of millions) either directly or indirectly, e.g.

- Directly, if they use satnav in their cars or on their mobile phones
- Indirectly, though delivery services that use satnav including aviation applications or banks that use Galileo time synchronisation.

For example, in 2010 a Department of Transport study estimated that 32% of cars had access to navigation devices. This figure is likely to be a significant underestimate of current values as Ofcom's 2015 annual Communications Market Report identified that 66% of adults in the UK owned a smartphone and hence are potential RNSS users.

Demand for spectrum is not driven number of end user terminals but rather the requirements of bandwidth (for resolution) and number of bands (to handle ionospheric delays better).

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).

Response:

UK consumers and citizens benefit in an extremely wide way from RNSS applications such as Galileo. The benefits includes which are quantifiable and also others which are non-quantifiable. Note that most of the value is at the user side and the majority of this usage involves the freely available service. Most of the value is at the user end and not visible to the RNSS community.

Direct UK involvement includes:

- Rutherford Appleton Laboratory (RAL) Chilbolton Observatory in the United Kingdom
- Surrey Satellite Technology Ltd (SSTL) for satellite construction.

SSTL has teamed with OHB System for the provision of the first 22 satellites in the full operational capability phase of the programme, with SSTL responsible for the navigation payloads on-board the satellite.

For the wider value to the UK, Europe and world-wide of Global Navigation Satellite Systems (GNSS) operating under the RNSS allocations, there are a number of reports and studies that are available including:

1. Global Navigation Satellite Service (GNSS) Market Report No. 4, March 2015
2. What is the Economic Impact of Geo-Services, Oxera Consulting Ltd, January 2014
3. Evaluation of Socio-Economic Impacts from Space Activities in the EU, Booz & co, February 2014.

This response will identify some of the high level findings and more detail can be found in these documents.

The Global Navigation Satellite Service (GNSS) Market Report No. 4 identified that:

- 3.6 billion GNSS devices in use globally in 2014, forecast to increase to 7 billion by 2019
- Within Europe there were on average 1.1 devices / capita in 2014, expected to grow to 2.1 by 2023
- Total estimated expected overall consumer benefits from navigation programmes on Europe would be around € 100 bn between 2014 and 2034.

The study by Oxera Consulting Ltd for Google on the impact of geo-services identified that:

a. The geo-services sector generates $ 150 - 270 bn of revenue globally, with a GVA (gross value added) of around $ 113 bn.

b. Geo-services also benefited greatly to consumers. A few examples:

i. Journey time and fuel savings from more efficient navigation could be worth $ 22 bn per year to consumers.

ii. In England, and looking at cardiac arrest only, geo-services may have saved 152 lives per year by reducing ambulance response/journey times.

iii. Geo-services applied to agriculture could save between $ 40 and 110 per hectare (counting only the benefits of a more efficient irrigation system).

The study broke benefits into the three categories of direct effects, consumer effects and wider economic effects. The study also provides a stylised value chain for geo-services.

While these studies often consider global or European benefits, the value to the UK is likely to be above that assuming simply pro-rata by GDP due to the UK's relatively rapid adoption of technology.

The UK citizens also gain value in terms of political and security benefits. A key objective of the Galileo system is to provide an independent satellite navigation and timing service for which political control is exercised by European countries such as the UK. The system has been designed with additional and specific security services including encryption and authentication to avoid spoofing and ensuring maximum flexibility and control over its usage, in particular within European territories.

The EGNOS system is proposed to be accurate and reliable enough for aviation applications. It includes adding an integrity signal to open services (with precision of 1m) to meet stringent requirements in safety-of life applications (e.g. aircraft landing).

Time services are critical to both mobile networks and banking – both industries in which the UK has world leading expertise.

RNSS will also be an enabler of spectrum sharing. For example, M2M applications including white space devices will use RNSS to identify their location as required to query database to identify available channels and associated maximum powers. RNSS cam also be an enabler for emerging technologies such as driver-less vehicles.

It is also mostly un-monetised – because the value is so widely gained it makes sense for it to be funded by governments as it is not feasible to (say) monetise the value of urban planning, improved. There is wider social value in:

- A mother driving her family using RNSS give directions being able to concentrate on road safety and her children
- Road users taking a more direct route, reducing their fuel costs and hence lowering harmful emissions including CO2 and NO2. These can assist in the UK achieving its objectives under international treaties to reduce greenhouse gases and pollution in urban areas (e.g. 9,500 dying in London due to poor air quality[2])
- Emergency services arriving earlier due to improved routing, saving lives and property.

It is noted that there are other RNSS networks in addition to Galileo. However:

- Having additional networks increases the likelihood of a lock: this is particular important in urban areas where there is building blocking direct paths to satellites

[2] http://www.theguardian.com/environment/2015/jul/15/nearly-9500-people-die-each-year-in-london-because-of-air-pollution-study

- Having additional networks increases the geographic range over which RNSS services are available, in particular at higher latitudes
- As noted above, there are geopolitical benefits in having assured access to RNSS services within the executive control of European countries such as the UK
- The Galileo network include specific features not available in the other networks, such as authentication while EGNOS includes the integrity signal.

Note that Galileo also includes a search and rescue payload which can be of benefit to UK citizens in distress while in remote locations.

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

Response:

See response to Q9 which covers Q8

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).

Response:

Growth is expected to occur in three dimensions:

1. Number of networks: it is notable that there are an increasing number of additional RNSS networks being deployed as other regional blocks and countries identify the benefits of having control over their own systems. It is expected that the number of systems will grow in the future.
2. Bandwidth of signal: in general, as the bandwidth increases there is a corresponding increase in accuracy and resilience.
3. Number of bands: multiple signals in different bands increases resilience, in particular as the different ionospheric delays at different frequencies can be used to better determine required corrections. Use of multiple frequencies also provides some mitigation against interference effects that only appear in one band.
4. There may be a call for dedicated bands for so-called “pseudolites”. These are terrestrial-based low-powered devices that emit RNSS-like signals intended to provide coverage indoors or in outdoor areas with reduced RNSS satellite visibility. Studies have shown that pseudolite emissions in the RNSS bands impact regular RNSS reception reducing performance or even jamming RNSS reception. Pseudolite manufacturers are therefore considering other frequency

bands and whilst this is not a traditional satellite application, pseudolites could form an integral part of RNSS based PNT in the future and could be regarded in some ways as an extension of RNSS systems.

The result is that additional spectrum could be required for RNSS growth in future, although likely not operationally within a ten year time frame.

In general these are global requirements, though European Geostationary Navigation Overlay Service (EGNOS) is a European specific overlay. There are equivalent overlays in other regions, including the US, Canada, Japan (and surrounding countries) and India.

Note that demand for RNSS is continual, not temporary or intermittent

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.

Response:

Galileo has been working to ensure have access to spectrum required for current and planned operations. This includes the bands listed above. The key difficulties are:

- Ensuring Galileo can continue to operate in existing bands without harmful interference e.g. potential deployment of mobile services in adjacent bands that could cause non-co-frequency interference
- Difficulties of coordination given number of other satellite systems, both RNSS and also for TT&C links in congested space operation frequencies at S-band

The issue of protection against harmful interference is of particular concern to the RNSS space to Earth links as the signals are extremely weak and ubiquitous coverage is required. There can be obstacles that reduce the number and quality of wanted signals (e.g. in urban canyons, where signal tracking or lock becomes very challenging or impossible) which makes this particularly sensitive to interference. Avoiding harmful interference from mobile services into RNSS receivers is hard to manage as there are two non-co-frequency paths:

- Transmitted in-band to one service but received out-of-band to the other
- Transmitted out-of-band to one service but received in-band to the other

This is made all the more difficult by the vastly different signal power levels of the two services - RNSS signals are received at levels below the noise floor.

Given the complexities of including high quality filters in small and low-cost devices (such as mobiles and RNSS receivers) the principle interference management technique is to ensure sufficient frequency separation between mobile transmit and RNSS receive frequencies.

Future operations could require access to additional bands in order to:

- Provide additional reliability
- Provide additional resolution.
- Provision for pseudolites to extend RNSS coverage indoors

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?

Response:

These mitigations would not assist in reducing the spectrum required by RNSS applications as:

- Global coverage is required, so even if it was feasible (it's technically very difficult) it would not be beneficial to use spot beam technology
- Similarly, at the receiver there is limited scope to improve antenna performance as typically there is only space on a handset for a very low gain antenna. Some specialised receivers used for reception of Galileo's secure and robust governmental service (PRS) will use sophisticated antennas currently subject to controlled access – this antenna technology will only be available to governmental users.
- Time (and hence location) differences are measured via phase detection, so accuracy is directly related to bandwidth. Therefore it not feasible to reduce the bandwidth without reducing location and time measurement accuracy. Furthermore, millions of receivers have already been deployed assuming the existing parameters of the Galileo system and the similar GPS and Glonass parameters. RNSS signals are extremely weak and operating any terrestrial services in this band or in adjacent bands could cause harmful interference over a large area, making it infeasible to gain a PNT solution. RNSS services are intended to be provided globally on land, sea and in the air without any gaps in coverage either geographically or in time
- RNSS satellites operate in non-GSO orbits where the concept of the orbital slot does not apply.

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?

Response:

None – RNSS is very sensitive to interference because received RNSS signals are very low power. RNSS systems (and some receivers) operate on very long scales and hence mitigations to facilitate sharing must be employed by other services, eg aviation safety critical receivers have typical 20-30 year life cycle. The most effective technique is to ensure there is sufficient frequency separation but it can also be important to ensure that any terrestrial applications in adjacent bands use tight OOB masks.

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.

Response:

The key requirement is to protect existing RNSS spectrum, in particular to avoid harmful interference from services in adjacent bands. As noted earlier, due to equipment constraints, the most effective technique is to ensure there is sufficient frequency separation but it can also be important to ensure that terrestrial applications in adjacent bands use tight OOB masks.

It is noted that Ofcom has a research budget and remit under the Communications Act to undertake research and this a potential output from the strategic review is the need for further research. For example, as this response has noted, it is difficult to gain definitive value figures for services such as RNSS and hence this is an area that could benefit from further research.

Space science respondents

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

Response:

It could be useful to have a separate concept of space science application (related to ITU-R service) to distinguish it from end user application (which are extremely extensive and open ended).

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?

Response:

As for Galileo, value is considered societal and so widely spread that it is not feasible to monetise the transactions. Hence service provided for free with value returning due to:

- Increased commercial activities, leading to increased GDP and tax revenues
- Social value
- Security and political benefits.

These are on a UK, European and global basis.

The majority of the value is in the end user sector, with only a small part in the previous five blocks in the chain in Figure 3.

Question 15: What is the extent of your organisation's 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.

Response:

This response provides information on the European Commission's activities relating to Copernicus including the Sentinel satellites. These include the following space science applications:

- Passive Earth sensing
- Measurement and dissemination of information relating to the weather and environment
- Active Earth sensing
- TT&C

The involvement in the value chain for these applications are as:

- Satellite Operator
- Network & service providers

- An example of an end user.

It is unlikely that the vast majority of end users are unaware of this CFI and would not respond (or even be aware that their activities are covered by this CFI). However these end users represent the majority of the value involved.

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.

Response:

Overview

The Sentinel satellites are currently being developed for the specific needs of the Copernicus programme. The Sentinels will provide a unique set of observations for Copernicus. They will consist of six different families:

- Sentinel-1 will provide all-weather, day and night radar imagery for land and ocean services. The first satellite (Sentinel-1A) was launched on 3 April 2014. The second one (Sentinel-1B) is planned for launch in 2015.
- Sentinel-2 will provide high-resolution optical imagery for land services. It will provide for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 will also deliver information for emergency services. The first satellite (Sentinel-2A) was launched in June 2015.
- Sentinel-3 will provide high-accuracy optical, radar and altimetry data for marine and land services. It will measure variables such as sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The first Sentinel-3 satellite is planned for launch in 2015.
- Sentinel-4 will provide data for atmospheric composition monitoring. Sentinel-4 will be a payload embarked on Meteosat Third Generation (MTG), which is scheduled to be launched around 2020 and which will be operated by EUMETSAT.
- Sentinel-5 will also be dedicated to atmospheric composition monitoring. Sentinel-5 will be a payload embarked on a MetOp Second Generation

satellite, also known as Post-EPS, to be launched in 2020 timeframe and which will also be operated by EUMETSAT.

- Sentinel-5 Precursor is a satellite mission planned to launch in 2015 in order to reduce data gaps between Envisat and Sentinel-5.
- Sentinel-6 will provide high accuracy altimetry for measuring global sea-surface height, primarily for operational oceanography and for climate studies. Sentinel-6A is planned for launch in 2020.

In addition, there will be Contributing Missions which are missions from ESA, their Member States, Eumetsat and other European and international third party mission operators that make some of their data available for Copernicus.

There are around 30 existing or planned Contributing Missions. They fall into the following categories:

- Synthetic Aperture Radar (SAR)
- Optical sensors
- Altimetry systems
- Radiometers
- Spectrometers.

Even when the Sentinels are operational, the Contributing Missions will continue to be essential, delivering complementary data to ensure that a whole range of observational requirements is satisfied.

The satellite infrastructure is supported by in situ sensors. Copernicus services rely on data from in situ monitoring networks (e.g. ground based weather stations, ocean buoys and air quality monitoring networks) to provide robust integrated information and to calibrate and validate the data from satellites.

Frequencies Used

The Sentinel missions are part of the EU Copernicus programme and are used for Earth observations purposes. Currently, several satellites missions are envisaged: Sentinel-1, Sentinel-2, Sentinel-4, Sentinel-5 (including pre-cursor) and Sentinel-6 (Jason–CS). Moreover, the so-called Sentinel-4 and Sentinel-5 are instruments included in commercial satellites (two Meteosat Third Generation-Sounder satellites - MTG-S1 and MTG-S2 - and MetOp-SG satellite A respectively).

In addition to the Sentinel missions, other Contributing Missions, commercial and/or institutional, are involved in the Copernicus programme (overall about 30 existing and planned missions). These missions employ payloads similar to the Sentinel satellites: SAR, optical sensors, radar altimeters, radiometers and spectrometers. For these types of payloads, C/Ku/K/Q bands are used.

It is important to mention that the optical data link EDRS (European Data Relay System) on-board Sentinel-1 and Sentinel-2 will interface with the EDMR satellite system currently under development by ESA and Airbus Defence and Space. A first EDRS instrument will be launched as payload in the geostationary satellite Eutelsat-9B (launch due in 2015). A geostationary satellite mainly focussed on the optical data link technology will then be launched in 2016 (EDRS-C).

Below is reported an overview of the communication links used by the Sentinel missions. The class of station fields are described in a table extracted from the preface to the BR IFIC.

<u>Sentinel-1:</u>

- X-band payload data downlink
- Optical data link through European Data Relay System (EDRS) for payload data at 520 Mbps
- S-band TT&C link: 64 kbps uplink, 128 kbps/2Mbps downlink
- Payload:
    - SAR (Synthetic Aperture Radar) C-band: 5.405 GHz centre frequency

Frequency data retrieved from the ITU Space Network Systems (No: 111500003):

Freq. (MHz)	Band. (kHz)	Fr. Band (MHz)	Class of station
Transmit beams			
2254.10000	2200	2253.0000 - 2255.2000	EK, ER, EW
5405.00000	100000	5355.0000 - 5455.0000	E3
8095.00000	140000	8025.0000 - 8165.0000	EW
8260.00000	140000	8190.0000 - 8330.0000	EW
Receive beams			
2075.650	768	2075.2664 - 2076.0344	ED, EK, EW
5405.000	90000	5360.0000 - 5450.0000	E3

Sentinel-2:

- X-Band payload data downlink
- Optical data link through European Data Relay System (EDRS) for Payload Data at 600 Mbps
- S-Band TT&C link: 64 kbps uplink with authenticated/encrypted commands, 2018 kbps downlink
- Payload:
    - MSI (Multi Spectral Instrument): 13 spectral bands in the range 443 nm–2190 nm (including 3 bands for atmospheric corrections)

Frequency data retrieved from the ITU Space Network Systems (No: 111500004):

Freq. (MHz)	Band. (kHz)	Fr. Band (MHz)	Class of station
Transmit beams			
2254.10000	2200	2253.0000 - 2255.2000	EK, ER, EW
8095.00000	140000	8025.0000 - 8165.0000	EW
8260.00000	140000	8190.0000 – 8330.0000	EW
Receive beams			
2075.650	768	2075.2664 - 2076.0344	ED, EK, EW

Sentinel-3:

- X-band science data downlink (2 x 280 Mbps)
- S-Band TT&C link (with ranging): 64 kbps uplink, 1 Mbps downlink
- Payload:
    - OLCI (Ocean and Land Colour Instrument): 21 bands spectrum (0.4-1.02) µm
    - SLSTR (Sea and Land Surface Temperature Radiometer): 9 bands spectrum (0.55-12) µm
    - SRAL (Sentinel-3 Ku/C Radar Altimeter): 13.575 GHz, 5.41 GHz centre frequencies
    - MWR (MicroWave Radiometer): dual frequency 23.8/36.5 GHz

- POD (Precise Orbit Determination):
  - GNSS receiver (Global Navigation Sat. System) (L1 C/A, L1P(Y) and the L2P(Y))
  - DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite
  - LRR Laser Retro reflector

Frequency data retrieved from the ITU Space Network Systems (No: 111500005):

Freq. (MHz)	Band. (kHz)	Fr. Band (MHz)	Class of station
Transmit beams			
2254.10000	2200	2253.0000 - 2255.2000	EK, ER, EW
5410.00000	320000	5250.0000 - 5570.0000	E3
8095.00000	140000	8025.0000 - 8165.0000	EW
8260.00000	140000	8190.0000 – 8330.0000	EW
13575.00000	350000	13400.0000 - 13750.0000	E3
Receive beams			
2075.650	768	2075.2664 - 2076.0344	ED, EK, EW
5410.000	290000	5265.0000 - 5555.0000	E3
13575.000	320000	13415.0000 - 13735.0000	E3
23800.000	400000	23600.0000 - 24000.0000	E4
36500.000	1000000	36000.0000 - 37000.0000	E4

Sentinel-5 precursor:

- X-band science data downlink (310 Mbps OQPSK)
- S-band TT&C link (with ranging and coherency): 64 kbps uplink, 128 kbps-1 Mbps downlink
- Payload:
  - TROPOMI UV-VIS-NIR-SWIR push-broom grating spectrometer: 270-495 nm, 710-775 nm, 2305-2385 nm spectral Range

Frequency data retrieved from the ITU Space Network Systems (No: 113500053):

Freq. (MHz)	Band. (kHz)	Fr. Band (MHz)	Class of station
Transmit beams			
2259.00000	1200	2258.4000 - 2259.6000	EK, ER, EW
8150.00000	233000	8033.5000 - 8266.5000	EW
Receive beams			
2080.163	768	2079.7790 - 2080.5470	ED, EK, EW

Sentinel-6 (Jason-CS):

- X-band science data downlink (150 Mbps at 8.090 GHz)
- S-band TTC link: 16 kbps uplink, 32 kbps downlink
- Payload:
  - Poseidon-4 (SAR Radar Altimeter)
  - AMR-C (Climate-quality microwave radiometer – NOAA/JPL contribution)

- GNSS–POD Receiver provides GNSS measurements for Precise Orbit Determination using GPS and Galileo signals
    - DORIS enables precise orbit determination
    - Laser Retroreflector Array (NOAA/JPL contribution) enables tracking by ground-based lasers
    - GNSS-RO (NOAA/JPL contribution) uses GNSS measurements for RO.

Filings not yet registered on ITU Space Network Systems.

Summary

The frequencies used by all Sentinel satellites excluding the Jason mission are given in the table below:

Freq. (MHz)	Band. (kHz)	Fr. Band (MHz)	Class of station
2075.650	768	2075.2664 - 2076.0344	ED, EK, EW
2080.163	768	2079.7790 - 2080.5470	ED, EK, EW
2254.100	2200	2253.0000 - 2255.2000	EK, ER, EW
2259.000	1200	2258.4000 - 2259.6000	EK, ER, EW
5405.000	100000	5355.0000 - 5455.0000	E3
5410.000	320000	5250.0000 - 5570.0000	E3
8095.000	140000	8025.0000 - 8165.0000	EW
8150.000	233000	8033.5000 - 8266.5000	EW
8260.000	140000	8190.0000 – 8330.0000	EW
13575.000	350000	13400.0000 - 13750.0000	E3
23800.000	400000	23600.0000 - 24000.0000	E4
36500.000	1000000	36000.0000 - 37000.0000	E4

A table with the definition of the class of stations is given below, taken from the preface to the BR International Frequency Information Circular BR IFIC (Space Services).

Symbol	Space Station Class of Station
E1	Space research (active sensor) space station
E2	Space research (passive sensor) space station
E3	Space station in the Earth exploration-satellite service (active sensor)
E4	Space station in the Earth exploration-satellite (passive sensor)
EA	Space station in the amateur-satellite service
EB	Space station in the broadcasting-satellite service (sound broadcasting)
EC	Space station in the fixed-satellite service
ED	Space telecommand space station
EE	Space station in the standard frequency-satellite service
EF	Space station in the radiodetermination-satellite service
EG	Space station in the maritime mobile-satellite service
EH	Space research space station
EI	Space station in the mobile-satellite service
EJ	Space station in the aeronautical mobile-satellite service
EK	Space tracking space station
EM	Space station in the meteorological-satellite service
EN	Space station in the radionavigation-satellite service
EO	Space station in the aeronautical radionavigation-satellite service
EQ	Space station in the maritime radionavigation-satellite service
ER	Space telemetering space station
ES	Station in the inter-satellite service
ET	Space station in the space operation service
EU	Space station in the land mobile-satellite service
EV	Space station in the broadcasting-satellite service (television)
EW	Space station in the earth exploration-satellite service
EY	Space station in the time signal-satellite service

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).

Response:

A number of reports are available that are the results of studies of the value of remote sensing data at different stages within the value chain and also within specific sectors, including:

1. Evaluation of Socio-Economic Impacts from Space Activities in the EU, February 2014
2. European Earth Observation and Copernicus Midstream Market Study, September 2013
3. Assessing the Economic Value of Copernicus: European Earth Observation and Copernicus Downstream Services Market Study, Final Report, December 2012
4. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Agriculture Sector, Final Report, December 2012
5. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Oil and Gas Extraction Sector, Final Report, December 2012
6. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Renewable Energy Sources Electricity Sector, Final Report, December 2012

7. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Water Transport Sector, Final Report, December 2012
8. Study on the Competitiveness of the GMES Downstream Sector, Final Report, February 2008

Value to UK citizens and consumers comes from a range of factors, and, as noted previously, many are not visible or hard to quantify. The first document gives a snap-shot which gives a feel for the variety of benefits to UK or European citizens. It describes "catalytic effects" which result from the benefits that government, consumers, society and other industries derive from specific space applications.

Area	Description	Value	Year
METEO	Improved weather forecasts	~ 580 to 1470 Mln Euro (UK economy alone)	2006
DISASTER Mngm.	Increase efficiency in natural disaster management cycle (conservative estimate, large EO programme)	Reduction of 1% in damages a year = ~ 100 Mln Euro/year (Europe wide)	2010
CLIMATE CHANGE	(Increased knowledge of climate change variables, case study sea level rise)	Reduction of 25% of uncertainly on climate change/sea level forecasts= saving in coastal protection of ~ 90-100 Mln Euro/year (Europe wide)	2008
ENVIRON. MNITORING	(Increased efficiency in sea resources monitoring case study France fish stock)	Reduction of 90% of cases of illegal fishing in 1 year from start of service (French EEZ, specific areas)	2005
	(Increased efficiency in detecting fraudulent behaviours, and ensure sustainable land exploitation, case study EU CAP subsidies)	Reduction of frauds from 2% to 0.02%of CAP budget = ~ 1bln Euro/year Incl. EO satellite contribution (Europe wide)	2006-2010
	(Increased operational efficiency in Oil spill monitoring, case study CleanSeaNet)	Reported costs saving in operations ~ 25Mln Euro/year (EMSA Opex)	2007-2011
DEFENCE	(Acquisition of sensitive VHR data for usage for defence and security)	Strategic access to sensitive data to plan military operations	Current
AGRI-CULTURE	(Increase efficiency in precision agriculture, case study Farmstar)	Cost saving in Nitrogen fertiliser and increase in crop yield leading to a net economic benefit • 5 Euro per hectare of wheat (EU adopters)	2003-current
MARITIME	(Improved ocean currents modelling for in route vessel optimisation)	Cost saving in vessel fuel for ~ 4% in average up to 8% (EU adopters)	2011
OIL & GAS	(Increased efficiency in identification of oil & gas reservoirs and monitoring of oil pipelines)	Cost reduction to identity new reservoirs, cost saving in monitor pipelines and in , etc	Current

Figure 1: Earth Observation Catalytic Benefits – European Case Studies Examples

Figure credit: Evaluation of Socio-Economic Impacts from Space Activities in the EU, February 2014

The wide variety of potential benefits and the distance between value benefit being realised and the space science operator makes it hard to give quantitative data. This is particularly the case as the Copernicus data is planned to be provided free of charge, and hence there is no mechanism to charge Copernicus data users or track the applications using the data. It is clear, however, that the end use value significantly exceeds the value of the upstream part of the sector, estimated in Europe to be € 900 million/year in 2011 or the mid-stream Earth Observation industry of € 750 Million in 2012.

There can be both direct and indirect benefits, for example:

- Remote sensing data is used within mapping applications, and, as noted for Galileo, this is globally a $ 150 - 270 bn sector with many value benefits for UK customers and consumers
- Remote sensing data includes weather forecasting, with benefits to the UK of € 580 to 1 470 million Euros, as in the table above
- Remote sensing data is required for UK's environmental policies, such as tracking CO_2 emissions

- Remote sensing data has applications for urban planning, agriculture, maritime and the oil and gas sectors
- Remote sensing data has security and military applications.

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

Response:

See answer to question 19.

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).

Response:

The EU is developing of a range of satellites to be launched over the next five years. These satellites typically have an operation lifespan of 7 years and consumables for 12, but there is also the need for continuous use of the same spectrum to ensure can observe trends. Hence it is expected that they would be replaced at end of life to avoid a gap in observations. Space science applications work in very long time scales and involve large investment from European countries, in particular the UK.

Specific frequencies required as governed by nature and physical laws and there is demand for higher resolution and increased number of observations, leading to greater bandwidth requirements.

While bandwidth and spectrum requirements are driven by observation types and resolution, the service scales with demand. However increasing bandwidth (leading to higher resolution) can open up potential for new applications.

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.

Response:

Key issue are (as mentioned previously):

- Protecting existing spectrum, in particular from terrestrial services interference - returned radar signals to the satellites are highly susceptible to interference as shown by ITU and CEPT studies, which is conclude that in-band sharing wit the mobile service is not feasible in the same geographic area; and as Copernicus is a global system, this is problematic.

- Coordinating with other satellite operators, in particular for TT&C
- Ensure have access to long term continuous measurements.

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?

***Response**:*

No.

Question 22: Do you have any comments on the list of potential mitigations we have identified? What likely impact would each of the mitigations have on spectrum demand? To what extent do you believe that these mitigations apply only to certain applications?

Response:

These mitigations will only have limited ability to facilitate spectrum sharing and could lead to harmful interference into space science applications. In particular:

Filtering

Copernicus satellites including Sentinel already include filtering to reduce interference from systems transmitting in adjacent band. However that is not on its own sufficient to protect against harmful interference. For example the SMOS satellite suffered harmful interference from services operating in adjacent bands (in particular radar and ENG applications) and the limiting constraint is more likely to be those system's spectrum masks. Ofcom should, therefore, have the improvement of terrestrial applications filtering rather than EESS receiver filtering.

Signal Processing

Modern digital communication systems have a noise like spectrum. This means it is very hard for interference from them to be distinguished from the noise signal that EESS satellites are attempting to measure. If there are a limited number of well-defined transmitters then it can be feasible to calculate their impact on raising the measured noise and hence subtract their signal. However this is only feasible for a number of services.

Global Database

While the global database appears to be an attractive solution there are many difficulties that the proponents have not addressed which make it infeasible. In particular:

- The satellite networks involved are global in nature, and hence the remit of the ITU. Yet the ITU does not have the capabilities or inclination to undertake global device authorization activities, in particular:
    - The ITU is not in a position to detect orbital elements of systems (it has no radars)
    - There are disagreements between member states that would make it politically infeasible to use a single source (e.g. NORAD)

  - The ITU is not able to identify what passive sensors a satellite is carrying. This is particularly an issue for those satellites that have dual use (i.e. a military aspect)
  - The ITU does not have an enforcement mechanisms to check that RLAN devices are deployed that meet the necessary standards e.g. switch off when commanded
  - There is no precedent of the ITU acting in this way in the Radio Regulations. No draft regulatory text has been proposed.
- There are many systems proposing to use the relevant bands (e.g. 5 350 – 5 470 MHz) limiting any potential spectrum efficiency benefits.
- If implemented at a country by country basis, it would require that all countries are equally vigorous in their spectrum management regimes, which introduces significant risk.
- Software defined radios that can be programmed to operate at any frequency could be more likely to operate on this band on an illegal basis if it is also used for widely deployed RLAN devices. Anecdotal evidence suggests this is already done today with existing RLAN devices.

Note that satellites are flown and being proposed that would have the ability to change their orbital at short notice, and the database would require the ability to disseminate updates very rapidly.

There is a danger that proposals for global databases distract from the longer term drivers of short range mobile communications, which could require consideration of higher frequencies above 60 GHz.

Improved Coordination

Satellite coordination is a complex task as Copernicus has to coordinate the satellite's TT&C in S band where there are literally hundreds of satellites. Therefore, introducing additional constraints, such as on where ES can successfully be coordinated with terrestrial services, could result in significant operational difficulties.

Note that at present the ground control stations are not located in the UK. However it would present a dangerous precedent for this band to be used in the UK for commercial terrestrial services that could lead to other countries following suite and constrain the ability to host ground control stations in the UK in the future.

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?

Response:

The most effective spectrum sharing technique is to ensure there is sufficient frequency separation but it can also be important to ensure that any terrestrial applications in adjacent bands use tight OOB masks.

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.

Response:

The key requirement is to protect existing space science spectrum, in particular to avoid harmful interference from services in adjacent bands. As noted earlier, due to equipment constraints, the most effective technique is to ensure there is sufficient frequency separation but it can also be important to ensure that terrestrial applications in adjacent bands use tight OOB masks.

It is noted that Ofcom has a research budget and remit under the Communications Act to undertake research and this a potential output from the strategic review is the need for further research. For example, as this response has noted, it is difficult to gain definitive value figures for services such as space science and hence this is an area that could benefit from further research.

In some cases, Ofcom’s studies as to new allocations for spectrum for mobile is being driven by manufacturer dominated organisations with a short term perspective. For example, it would be better if the need for high data rate short range communications was analysed at a strategic level so that options to RLANs at 5 GHz such as moving to higher frequencies (e.g. above 60 GHz) could be included in Ofcom’s considerations.