uk spectrum policy forum

UK Spectrum Usage & Demand

Second Edition – Summary Report

Prepared by Real Wireless for UK Spectrum Policy Forum

Issue date: 16 December 2015

realwireless
independent wireless experts

Real Wireless Ltd
PO Box 2218
Pulborough
West Sussex
RH20 4XB
United Kingdom

t +44 207 117 8514
f +44 808 280 0142
e info@realwireless.biz
www.realwireless.biz

uk spectrum policy forum

Real Wireless Ltd
PO Box 2218
Pulborough
West Sussex
RH20 4XB
United Kingdom

t +44 207 117 8514
f +44 808 280 0142
e info@realwireless.biz
www.realwireless.biz

realwireless
independent wireless experts

About the UK Spectrum Policy Forum

Launched at the request of Government, the UK Spectrum Policy Forum is the industry sounding board to Government and Ofcom on future spectrum management and regulatory policy with a view to maximising the benefits of spectrum for the UK. The Forum is open to all organisations with an interest in using spectrum and already has over 150 member organisations. A Steering Board performs the important function of ensuring the proper prioritisation and resourcing of our work.

The current members of the Steering Board are:

Airbus Defence and Space	Huawei	Sky
Avanti	Ofcom	Telefonica
BT	QinetiQ	Three
DCMS	Qualcomm	Vodafone
Digital UK	Real Wireless	

About techUK

techUK facilitates the UK Spectrum Policy Forum. It represents the companies and technologies that are defining today the world we will live in tomorrow. More than 850 companies are members of techUK. Collectively they employ approximately 700,000 people, about half of all tech sector jobs in the UK. These companies range from leading FTSE 100 companies to new innovative start-ups.

About Real Wireless

Real Wireless is the pre-eminent independent expert advisor in wireless technology, strategy & regulation worldwide. We bridge the technical and commercial gap between the wireless industry (operators, vendors and regulators) and users of wireless (venues, transportation, retail and the public sector) - indeed any organization which is serious about getting the best from wireless to the benefit of their business.

We demystify wireless and help our customers get the best from it, by understanding their business needs and using our deep knowledge of wireless technology to create an effective wireless strategy, business plan, implementation plan and management process.

We have specific experience in LTE, LTE-A, 5G, UMTS, HSPA, Wi-Fi, WiMAX, DAB, DTT, GSM, TETRA, PMR, PMSE, IoT/M2M, Bluetooth, Zigbee, small cells, radio, core and transport networks – and much more besides.

For details contact us at: info@realwireless.biz

www **Tap into our news and views at: realwireless.biz/blog**

Stay in touch via our tweets at twitter.com/real_wireless

Foreword by David Meyer
Chair of UK Spectrum Policy Forum

Spectrum is the hidden resource which enables and underpins the way we live now – access to the internet, entertainment, managing air rail road and ship movements, and much more. For the future, spectrum will enable ever greater changes – transforming our health services, creating and supporting communities from the very local to global. From these services, spectrum delivers significant economic value to the UK – estimated[1] as £52 billion in 2011 – but also social value. The UK government has set out a vision for spectrum to double its annual contribution to the economy by 2025.

But given that the available spectrum is finite, realising that vision requires that the wide range of spectrum users find ways to occupy the spectrum more densely, more efficiently and more flexibly. Given their diverse range of needs, meeting the growing demand requires a coordinated approach across users, and mutual tolerance of different needs.

Fostering that mutual tolerance is exactly the aim of the UK Spectrum Policy Forum. Since the Forum was launched in earnest in September 2013, we have sought views on the importance of spectrum as a UK national resource. These views have come from a very wide cross-section of sectors, many of which have critical business and social requirements for spectrum. Based on these views, we have identified spectrum "pinch points" which must be addressed if we are to maximize future growth in spectrum value. These will help government and Ofcom set and deliver long-term spectrum policy for the coming decades to help drive social and economic benefits, both via more effective spectrum usage within the UK, and via the consequent contribution of UK and international innovation and growth.

As independent chair of the Forum, I am keen that these views on spectrum needs across a wide range of industries are communicated widely, thereby helping to promote mutual understanding amongst spectrum users and to inform future policy debates. Inevitably the contents represent only a snapshot of views amongst a specific set of users at a particular time. Some of the views – which are those of the contributors, not of the Spectrum Policy Forum as a whole – may be mutually contradictory and reflect very different priorities. But such diversity represents the reality of modern spectrum usage and we feel it is better to air these views to foster progress than for them to remain obscure.

Membership of the Forum is free and open to all spectrum users – if you fit that description I encourage you to get in touch, and to participate in our work in the months and years to come.

David Meyer

[1] By Analysys Mason for DCMS/BIS in report published November 2012, https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand

Acknowledgements

This report has built on the contributions of many individuals from many organisations within the UK Spectrum Policy Forum. Our thanks in particular are due to the following organisations.

Space: UK Space Agency BBC Viasat Astrium Eutelsat Inmarsat Avanti SES Airbus DJCSL	**Defence:** QinetiQ Ministry of Defence BAE Systems Thales
Business radio: Airwave Ofcom TETRA and Critical Communications Association (TCCA) Federation of Communication Services	**Short range wireless:** BAE Systems Sky
Meteorology: The Met Office	**Broadcasting & Entertainment:** Arqiva BBC Microsoft BEIRG Sennheiser Digital UK Sky DTG
Public Mobile: EE Telefónica -O2 BT Three Ofcom Samsung Vodafone	**Fixed Wireless Access & Wireless Transport Networks:** Independent Networks Cooperative Association (INCA) UK Broadband EE
Amateur Radio The Radio Society of Great Britain	**Utilities:** Joint Radio Company

Contents

Executive Summary

This report provides a snapshot of the current spectrum usage and expected long-term future needs of the major users of spectrum in the UK. It identifies the business and societal activities which depend on this spectrum and the associated drivers of value. The report was commissioned by the UK Spectrum Policy Forum and is based on contributions from a wide range of spectrum users.

Spectrum is a national asset that is increasingly subject to international developments and which, if appropriately distributed and used, can yield substantial economic and social value for the UK via a wide range of services and applications. In 2014 the Department for Culture, Media and Sport, which is responsible for UK spectrum policy as a whole, set out a vision for spectrum to double its annual contribution to the economy from a base of over £50 billion a year by 2025 through offering business the access it needs to innovate and grow, and everyone in the UK the services they need to live their lives to the full.

The report identifies 11 distinct sectors making use of UK spectrum. By promoting mutual understanding between sectors the report aims to assist in forming polices which will maximise spectrum value for the UK. The sectors are:

- Public mobile
- Utilities
- Business Radio
- Space
- Meteorology
- Defence
- Transportation
- Broadcasting and Entertainment
- Short range wireless
- Fixed Wireless: Access and Transport Networks
- Amateur radio

Across sectors a set of 'pinch points' and common themes are identified, which may constrain the value of services if not addressed appropriately. These pinch points include:

- An insufficiency of spectrum to support the capacity needs of sectors experiencing and expecting substantial growth in demand;
- Threats to current services from spectrum demand from other sectors, either via changes to spectrum allocations or from interference, creating challenges in promoting future investment;
- The need to align UK spectrum policy with international policies in order to promote economies of scale in equipment and open access to services;
- Tensions between public sector and private use of spectrum;
- Tensions between exclusive licensing and licence-exempt spectrum access;
- Tensions between public access and critical communications
- Immaturity and lack of regulatory clarity of newer models for spectrum access such as spectrum sharing and policies regarding spectrum pricing.

It also identifies how the future work programme of the UK Spectrum Policy Forum seeks to address these. It will do this via work areas such as:

- Exerting a positive influence on the UK position in EU and ITU
- Engaging Government Ministers to ensure spectrum remains high on their agenda
- Progressing long-term goals such as enabling greater access to spectrum held by the public sector

1. Overview

Spectrum is a national asset that is increasingly subject to international developments and which, if appropriately distributed and used, can yield substantial economic and social value for the UK via a wide range of services and applications. In 2014 the Department for Culture, Media and Sport, which is responsible for UK spectrum policy as a whole, set out a vision for spectrum to double its annual contribution to the economy from a base of over £50 billion a year by 2025 through offering business the access it needs to innovate and grow, and everyone in the UK the services they need to live their lives to the full.

The value of spectrum arises from both social and economic contributions made by a diverse set of services delivered by a wide range of industrial sectors. The finite nature of spectrum, and the differing technical and industrial characteristics amongst spectrum bands, often lead to competition for spectrum resources and challenges in avoiding harmful interference between services. Resolving such challenges is essential to maximising spectrum value and requires mutual understanding amongst users from different sectors to find ways to accommodate long-term needs, promoting additional investment and maximising innovation and growth in associated benefits.

To that end, the UK Spectrum Policy Forum was launched in September 2013 at the behest of Ed Vaizey, Minister for Culture and the Digital Economy to act as the industry sounding board on long-term UK spectrum issues to Government and Ofcom. This report provides a snapshot of the current spectrum usage and expected long-term future needs of the major users of spectrum in the UK. It identifies the business and societal activities which depend on this spectrum and the associated drivers of value.

The report identifies 11 distinct sectors making use of UK spectrum, and provides a snapshot of the current and future status and spectrum needs of each of these, based on inputs from leading players in the sectors themselves. Across sectors a set of 'pinch points' and common themes are identified, that may constrain the value of services if not addressed appropriately. It also identifies how the future work programme of the UK Spectrum Policy Forum seeks to address these.

It is hoped that this report will promote a joined-up understanding of current and future spectrum needs across UK users, thereby assisting in maximising associated benefits (social and economic) and ensuring spectrum supply can be efficiently matched to those needs.

2. Contents

This report provides four main views of spectrum requirements:

1. First we define the **scope** of each sector and an explanation of the spectrum-related **pinch points** faced by each sector
2. We then identify **common themes** which are faced by multiple sectors and where concerted action may yield substantial benefits
3. We explain how the Spectrum Policy Forum's future **work programme** will address these pinch points and common themes
4. We provide **sector summaries** giving details of the current status and expected future evolution in each sector

Appendices to the report then provide a comprehensive account of each sector.

3. Sector Scope and pinch points

For each spectrum-using sector, we explain below its scope (the range of activities addressed) and identified "pinch points", by which we mean spectrum-related issues which may limit the social and/or economic value of a given sector's output. Examples include:

- A need for access to additional spectrum which would otherwise limit growth
- A threat to existing spectrum from a need to vacate the spectrum which will affect future services with an expected demand
- Harmful interference to existing spectrum, limiting quality of service and/or increasing delivery costs
- A lack of alignment with international bands, limiting the availability and increasing the cost of equipment

The pinch points identified for each sector are as follows:

3.1 Public mobile

Sector Scope: Operators providing voice, text and data services over wireless mobile networks

Pinch points:

Many of the pinch points for mobile stem from the fact that there has been rapid growth of mobile traffic in recent years as this is expected to continue, and MNOs will need to employ a range of techniques to meet this demand, each of which introduce significant issues.

1. Additional spectrum is a key component to support cost-effective capacity increases. Growth in the supply of mobile spectrum is being heavily out-paced by growth of mobile demand, and this has resulted in a large disparity between the pricing of spectrum for mobile and for other uses, especially at lower frequencies. This situation is unsustainable in the context of stagnating operator revenues.
2. For additional spectrum to be widely usable for mobile, it must be in internationally harmonised bands in order to achieve the economies of scale necessary to ensure availability of cost-effective equipment and devices.
3. The process of spectrum harmonisation takes a long time, making it critical that enough spectrum is identified for allocation to mobile in good time so that demand can continue to be met by harmonised spectrum.
4. Combinations of licensed and licence-exempt spectrum are increasingly vital to operator networks. However, licence-exempt spectrum is and will remain a complement to rather than a replacement for *de facto* exclusive licensing for MNOs, whose ability to be able to ensure customer experience is vital.
5. Looking forward to 5G, this will require:
   I. large allocations of contiguous spectrum in bands in the 6 GHz to 100 GHz range;
   II. additional spectrum below 6 GHz; and
   III. efficient and intensive use of existing spectrum holdings.

6. On (I), co-ordination to achieve harmonisation will be particularly important for bands above 6GHz, as there are many potential options for re-allocation of spectrum bands above 6GHz to mobile and technology becomes more tightly linked to specific spectrum bands at these higher frequencies.
7. On (II), this continuing need for macrocell capacity spectrum is vital to ensure that increasing demand for mobile data can be met both UK-wide and cost-effectively. The release of the 700 MHz band for mobile is welcomed, but more will need to be done to keep up with demand, especially for M2M applications.
8. On (III), operators will need to meet increased demand not just by increasing capacity using traditional wide area capacity solutions; they will need to adopt a range of solutions to meet demand, including more targeted, short-range solutions such as small cells. This has two implications:
    a) In order to maximise the potential for spectrum re-use, there are issues around planning for both macrocells and small cells that will need to be addressed e.g. site rental, infrastructure access and backhaul, so that spectral efficiency can be maximised.
    b) Re-farming of spectrum from 2G and 3G towards 4G and beyond will be vital, although this will be complex given the task of balancing the serving legacy devices and at the same time maximise available 4G capacity.
9. It is important that Government and regulatory policy provides the right climate to encourage further investment by creating certainty and stability, for example through long spectrum licence duration and avoiding charges or 'taxation' in the form of high annual licence fees which can discourage investment and by adopting a consistent pricing approach across all spectrum.

3.2 Utilities

Sector scope: Organizations supporting the generation, transmission and distribution of gas and electricity, excluding retail supply; the supply of water plus flood controls; waste water and sewage disposal.

Pinch-points:

1. Large increase number in data monitoring points – some high bandwidth applications but many rely on large numbers of small but critical data transmissions to support smart grid and analytics. Utilities need a network optimized for these data patterns and with prioritization for critical use.
2. Economic pressure to use public LTE network but potential risks to security, resilience and availability, which could have a detrimental effect on effectiveness of smart grid.
3. Optimum levels of security, coverage and availability could come from dedicated UHF-band spectrum but the spectrum would have to be paid for at market rates.
4. QoS prioritization – some operators may be reluctant to entertain prioritisation of selected groups of users on the network because of regulatory issues or detrimental impact on their customer base. In addition, Service Level Agreements (SLA) and compensation for lack of service do not mitigate the regulatory burden on the utilities to guarantee safety and provide service.
5. Many applications see the UHF band as optimal for coverage/ubiquity and indoor penetration. Capacity may be limited, but is likely to be adequate for utility requirement up to 2030, and has the added advantage that many utility

companies already have radio infrastructure designed to cover their service area at UHF frequencies.

6. Shared access in 870-876 MHz is used for mesh and meters but is in limited use currently due to a lack of protection. Further deployment depends on sharing mechanisms being robust. Licence-exempt 868 MHz has been decided as the basis for some smart electricity meters, and may also be an option for water meters, but there are debates over increasing congestion.
7. For future requirements the relevant spectrum has yet to be identified: options include 450 MHz, 700 MHz or use of managed resilient M2M services from mobile operators. 1400 MHz is also of interest in some applications to the extent that it is not required for mobile broadband.

3.3 Business Radio

Sector scope: A very diverse sector covering emergency services communications, maritime communications and PMR (private mobile radio) for a wide range of vertical markets. Some users outsource the management of their PMR system to third parties such as Airwave (emergency services) or Ambitalk (more general users) in a model known as PAMR (Public Access Mobile Radio), which is done through an opex model (monthly rental of radios). However the vast majority of PMR schemes today are capex-based, with the users owning their own terminals and infrastructure.

Pinch-points: General BR

1. BR's requirements are different to those of public mobile – due to requirements such as PTT, P2P, D2D and PMP connection for large groups; enhanced encryption etc. – yet there is a move to run these services in public mobile spectrum/networks
2. 700 MHz spectrum will be hotly contested, with very different dynamics if there is a dedicated sub-band for ES. 450 MHz and below have been deprioritised but are still of great interest for BR, especially for IoT/M2M, and even down to 380 MHz, though NATO may object to that.
3. No interest from MNOs in cellular for 450 MHz but it does suit telemetry in combination with licence exempt spectrum for indoor use. If Ofcom re-aligns UHF with bandplans elsewhere in Europe it will allow spectrum for Emergency Services legacy use, additional spectrum for PMR, allocation for PMSE, Maritime, Scanning Telemetry, possible allocation for CNI requirements.
4. There is a need for more sharing, via DFS and other mechanisms, but processes uncertain especially for critical usage.

Pinch-points: PPDR/ES

5. Data becomes mission critical but there is insufficient capacity in current TETRA spectrum. Can these be supported if data usage (and even voice) is delivered over public LTE in 800 MHz/700 MHz?
6. Sub-optimal spectrum or network could compromise critical communications quality.
7. Hardened LTE networks not ready yet (Release 13 and 14), MNOs may be reluctant to dedicate capacity which could be used for more lucrative customers.
8. Future of voice post-TETRA is a major issue, major questions marks over whether VoLTE will ever be mission critical

Pinch-points: PMR

9. More efficient technologies outweighed by rise of critical data – net spectrum capacity loss for BR.
10. Rising use of data and of PMR licence numbers – congestion in existing bands which are already fragmented. Licences will never run out, but spectrum capacity may, particularly in conurbations, impacting on QoS.
11. Need for harmonisation - manufacturers are not interested in UK-only bands or spectrum below 136MHz for digital.
12. PMR may be business critical (e.g. keeping an airport running) and even have safety implications, creating risks of running such services over public LTE networks. There will always be a need for private networks – will we see private LTE or only public providers, and how will sharing be supported? Can non-ES users get guaranteed QoS from MNOs affordably?
13. Continuing use of analogue services e.g. London Buses. There is still a limited analogue requirement in Low Band for wide area services such as PAMR. Ofcom is maintaining a technology neutral approach, so market forces will determine if analogue is removed as a choice for customers. Some industries such as utilities are still investing in multimillion pound analogue trunked networks, waiting for digital trunked to prove itself and nervous about being early adopters. Responses to the UHF survey showed that analogue is preferred by customers over digital, requesting that Ofcom does not abandon analogue for at least 10 years (most radios are dual-mode in the UK).

3.4 Space

Sector scope: Remote sensing, Science and exploration, Navigation and Communications services. As well as communications, the space sector enables services in finance, agriculture, transport, defence, planning, public protection, disaster relief and a host of others.

Pinch-points:

1. Ka-band increasingly necessary to support high-rate services, including mobile broadband, but most of the spectrum is also allocated to terrestrial services. Hence satellite faces technical challenges due to density of fixed services in some of the current allocations (e.g. 17.7 - 19.7 GHz) and some parts of the range27.5 - 29.5 GHz have been auctioned for fixed use.
2. Potential reduced utility of the C-Band because of the identification of parts of the band 3400-4200 MHz for broadband mobile access around the World. For example, half the band is identified for mobile in Europe, and Ofcom is investigating shared use in the remaining half. This band is important for feeder links, backhaul and service links in high rainfall areas.
3. Impact on Earth Observation SARs in 5350 MHz-5470 MHz if this is made an extension band for WLAN
4. 1 400 – 1 427 MHz: unwanted emissions from adjacent allocations into this passive remote sensing band
5. Potential interference from terrestrial IMT in and adjacent to 1 518-1 559 MHz used by Inmarsat

6. Use of the MSS 2GHz bands outside of Europe by terrestrial IMT systems, which could cause harmful interference to planned European MSS systems
7. Satellite bands above 6 GHz (e.g. C-band, Ku-band and Ka-band) are threatened by identification of IMT/5G spectrum, which might jeopardise and disrupt extensive investments already made by UK-based satellite operators
8. Also potential threats to 1 675 – 1 710 MHz bands (meteorological satellites), 2 025 – 2 110 MHz and 2 200 – 2 300 MHz (space research, EESS and space operation services) from IMT
9. Huge deployment of constellations of new LEOs planned for broadband services and EO (900 satellites in Ku-band, 4000 satellites for EO, 150,000 satellites from France) which will require coordination with existing users and broader regulation
10. Increased use of small satellites, possibly for 5G coverage, will have sharing implications – WRC-19 agenda item on nanosats in UHF band
11. Spectrum dedicated for satellite services (L, S, C, X, Ku, Ka, Q/V bands) is often proposed as a candidate for increased sharing with terrestrial services, which creates unreliability and deters long term investment
12. FSS operators seek to expand X, Ku and Ka-band spectrum to meet increased demand
13. Increased demand for the quality of Earth Observation applications will require additional spectrum:

    - for X band EESS with an extended worldwide allocation up to 600 MHz for higher resolution images in all weathers
    - allocated in the 7-8 GHz band to EESS Earth to Space for high rate payload control and data links given S band congestion
    - extension of the current EESS (active) allocation around 9 400 MHz by 600 MHz to meet the need for higher resolution and 4D

3.5 Meteorology

Sector scope: Meteorology provides a wide range of weather forecast and warning services to the public, emergency responders, defence, aviation, industry and a range of other stakeholders across Government, underpinning the protection of life and property. Almost all of the observational data that is received and used for meteorology involves the use of the radio spectrum

Pinch-points:

1. Little change in spectrum requirements even in the longer term: increases in data volumes (from future satellite missions etc.) are likely to be balanced by technological advances and improvements in efficiency
2. The Met Office is open in principle to releasing any spectrum no longer required such as 137-138MHz which is no longer used in the UK by the Met Office.

3.6 Defence

Sector scope: The defence sector consists of the armed forces, under the auspices of the Ministry of Defence, as well as all their suppliers and contractors. Activities include systems and operations on land, sea, air and space.

Pinch-points:

1. Increasing use of spectrum in defence activities: smart defence, UAVs, ISTAR all require real time ultra-reliable wireless – but there are cost pressures.
2. In cyber defence and operations spectrum becomes operational environments and territorial advantage/disadvantage.
3. MoD manages about 35% of FAT (though around 85% of that is shared already) – pressure to share or repurpose to support government mobile broadband targets at a time of increasing spectrum usage for critical applications. 190 MHz to be released plus increased sharing in many bands – increasingly practicality dictates a focus on sharing rather than full release.
4. New spectrum requirements e.g. unmanned warfare but capacity requirement often uncertain – danger of giving away too much and being exposed later.
5. HMG wants to spend more on special forces and UAVs – technology more than troops – drones etc. will need “a fair amount of spectrum” to avoid mission failure and loss of life. WRC Agenda Item 1.5 covers wide range of potential airborne frequencies. ICAO – a question whether this is safe especially where close to mobile and satellite at 2-3 GHz, Ka-band and L-band
6. This balance will require new mechanisms for sharing e.g. cognitive radio. These do not all have to be complex new technology but can involve broader application of simpler workable approaches like geographical sharing.

3.7 Transportation

Sector scope: Services and equipment for carrying goods and people on aircraft (private and commercial), trains, metro/city transportation systems, ships (including fishing), and road vehicles. All of these are increasingly dependent on wireless connections for communications, customer services, navigation, security and safety, and automated control.

Pinch-points:

Aviation

1. There is an intention to study a long-term global air traffic system for potential operation around 2060 supported by internationally harmonised spectrum
2. 150 MHz of additional spectrum is needed for beyond line-of-sight control of remotely piloted aircraft, with progressive introduction for automating conventional aircraft and small drones. Although some allocations were addressed at WRC12, allocations for this application are being sought at WRC-15 but there is pressure to use non-safety spectrum for these purposes, which would not be appropriate from an aviation perspective.
3. The status of spectrum for space planes in the radio regulations is unclear as they would operate at altitudes beyond what would be perceived as a terrestrial service, but would not be satellites: it is not clear whether they should fit into aviation or space allocations and research including sharing studies is needed to resolve this.
4. Possible release of 100 MHz in 2.7-2.9 GHz for mobile broadband during 2016-2020 would involve moving radars to operate in the upper end of the band (modern radars cannot usually be retuned), or in 2.9-3.1 GHz and possibly replacing existing radars with new technologies in other bands, though most

would need to be replaced not retuned to go above 2.9 GHz, and new radar for those bands are not fully developed yet. This programme is further complicated by the use of the band by MOD for ATC radars.

5. Wireless avionics will drive additional usage of existing allocations of spectrum on shared basis as more engine functions can be monitored. Also, radar on aircraft wing-tips may reuse spectrum for automotive radar to assist navigation on the ground.
6. To address rising congestion in VHF bands, aircraft are being fitted with 8.33 rather than 25 kHz narrowband VHF radios.
7. Some S-band spectrum used by aviation may be released over the long term (25-30 years), enabled by more efficient technologies, although this remains an aspiration rather than a commitment.
8. Passenger communications approach unclear: may mix terrestrial, satellite, and inter-plane meshes.
9. There is increasing pressure to share spectrum with non-aviation systems in globally harmonised aviation bands that are in current use and within which aviation is planning to expand its capabilities in the next 5 – 10 years to support, for example the increase in the use of aircraft data links. It is of concern as to how aviation operations would be guaranteed in a sharing environment and if interference was to be experienced then to maintain safety levels it may be necessary to restrict aviation operations, which could have significant economic impact for the UK and affect the travelling public. It is also of concern that such near term sharers may then restrict aviation in the UK from implementing new internationally standardised systems, where doing so may be part of the UK's international obligations.
10. Spectrum pricing and public sector spectrum release programmes create significant uncertainties for aviation and because these spectrum efficiency initiatives are currently only UK-centric, they raise issues in respect of international programmes and relationships.
11. The status of spectrum for space planes in the radio regulations is unclear as they would operate at altitudes beyond what would be perceived as a terrestrial service, but would not be satellites: it is not clear whether they should fit into aviation or space allocations and research including sharing studies is needed to resolve this.
12. Aviation is currently working on a global aeronautical distress & safety system intended to improve the monitoring and, in times of distress, reporting of aircraft locations on a global basis, especially in remote and oceanic areas. This may require new spectrum allocations and this is under study.
13. Wireless avionics will drive additional usage within aviation of existing frequency bands, e.g. communications within a single aircraft to allow sensors to be deployed around the airframe where none is currently possible. In addition, radar on aircraft wing-tips to provide taxiing guidance may reuse spectrum and technology for automotive radar.
14. To address rising congestion in the VHF communications band, aircraft are being fitted with multi-mode 8.33 and 25 kHz narrowband radios.

Road

15. Networks for bus and other road transport may increasingly make use of LTE as new features and operator SLAs evolve. In the medium to long term, commercial LTE networks could be the primary ones for data, and the fallback for voice

16. Smart transport and connected vehicles developments drive changes to spectrum usage. ITS is in European harmonised 5875-5905 MHz, but estimates suggest 80 MHz is needed for sufficient reliability
17. Connected car services, some city-driven applications like smart parking, increasingly rely on licence-exempt 868 MHz spectrum and there are risks of congestion

Maritime

18. Transition to digital radio systems supports new services (E-navigation & 'single window') and creates spectral efficiencies, but may still need new sub-1GHz allocations for capacity
19. There will be additional service provision in GMDSS (global maritime distress and safety system), as well as improved, and increased, usage of on-board UHF communications. New radar technologies may yield greater spectrum efficiency.
20. On-board communications must be globally harmonised, may take 20 years to make a change e.g. in UHF

Railways

21. Radio systems will eventually replace lineside telephones to avoid issues from wire theft and increase reliability
22. Increasing use of M2M for monitoring but applicable spectrum not clear
23. Specialised systems for providing passenger Wi-Fi and cellular need significant investment supported by spectrum
24. While GSM-R will becomes universal with GPRS capability added, limited equipment supply limits upgradeability, and long-term replacement path beyond obsolescence in 2024 not clear
25. In some views a Future Railways Mobile teleCommunications System (FRMCS) would require at least 10 MHz of new spectrum e.g. 872-876/917-921 MHz, 700 MHz or 400 MHz
26. London Underground TETRA will need replacement, likely by LTE, but deep coverage is challenging. Post-Airwave issues for all orange light users if they are left out of ESN. These services may not be life-critical but they are business critical if services fail – where is the line drawn?
27. LUL is also seeking spectrum for a wireless data network for trains, handheld devices and CCTV

3.8 Broadcasting and Entertainment

Sector scope: Broadcasters delivering radio or TV programming over terrestrial radio networks (digital terrestrial TV or DTT)[2]. This sector also includes the PMSE (programme making and special events) segment. This contains providers and operators of audio equipment for public events and live content creation, mainly wireless microphones and in-ear monitors as well as wireless cameras and video links

[2] Mobile and satellite delivery of TV is addressed in the relevant individual sectors

Pinch-points:

1. Like most countries with widespread take-up of terrestrial broadcasting, UK likely to retain DTT as most-used platform. Rising need for capacity e.g. demand likely to offset greater efficiencies of digital technologies
2. Risks associated with reallocation of 700 MHz, moving DTT and PMSE to 600 MHz. Loss of 800 MHz and 700 MHz may affect investment as well as QoS at a time of high competition.
3. Blurring lines with fixed and mobile IP distribution – growing consumer relevance of connected TV, future technical options for TV over LTE.
4. Limited options for new DTT/PMSE allocations
5. Beyond 2025 – fully converged TV/IP network to support broadcast, unicast and mobile might entail new approach to spectrum but many technology and policy changes needed first
6. Interoperability is essential for a healthy broadcasting ecosystem. In the UK the DTG has been an effective forum for agreeing interoperability requirements and test regimes, enabling UK to be an early adopter of HD on terrestrial television using the H.264 encoding standard and the DVB-T2 modulation standard, achieving a step change in spectral efficiency.
7. PMSE:
    - Rising demand and for more sophisticated shows.
    - Cannot use digital technology in many cases.
    - EC recommends 60 MHz for audio PMSE but some scenarios require 100 MHz. Interference risks when sharing with LTE.
    - Video PMSE is also undergoing change with an expected move to 7 GHz and 2 GHz following auction of the 2.3 and 3.4 GHz bands.
8. White space usage of UHF opens opportunities for innovation but capacity varies greatly and creates interference uncertainties

3.9 Short range wireless

Sector scope: This spans two rather distinct sets of technologies: Short Range Devices (SRDs) and Wi-Fi, with distinct user bases and applications. However, they often share the same licence-exempt spectrum and their future evolution requires joint consideration.

Pinch-points:

1. Higher frequency bands are under consideration for future SRDs, including for high resolution sensors and other general purpose devices. The huge swathe of spectrum between 200 GHz and 600 GHz is the subject of an ITU proposal for very high rate short range communications for interchip and other applications: the proposed CEPT ECP is now for 275-450 GHz to cover fixed/mobile use
2. There are competing views on future spectrum policy for licence-exempt spectrum, with some advocating much broader and more liberal application of licence-exemption, while others favour a more regulated approach to band planning within LE spectrum to minimise congestion

3. There are tensions between the use of some bands, notably 5 GHz, with very different requirements between applications such as consumer access and industrial automation. Inefficiencies currently arise from dynamic frequency selection (DFS) requirements, and there may be future prospect for better management via databases etc.
4. 5GHz is also likely to see new usage from LTE-style technologies such as LAA-LTE and LTE-U which use 5 GHz and other licence-exempt bands, either in conjunction with licensed spectrum or in isolation. This could put further pressure on Wi-Fi services at hot spots.

3.10 Fixed Wireless: Access and Transport Networks

Sector scope: The sector covers any services delivered over wireless networks with no mobility in the end points, primarily fixed links, mobile backhaul, wireless broadband access, and private enterprise networks. There is a wide range of operators from community access providers to WISPs to national operators. Mobile operators usually deploy their own wireless backhaul but there may be an emergence of 'as a service' providers in the Wi-Fi and small cell areas.

Pinch-points:

1. Main market mobile backhaul – new mobile topologies drive FWS spectrum needs. Increasing capacity, move to small cells and C-RAN/fronthaul.
2. Do those mobile needs squeeze out other business cases – altnet, smart cities, rising demands for rural capacity/QoS and urban infill?
3. Backhaul or access in high bands e.g. 60 GHz?
4. Public mobile and FWS expansion (smart rail, smart city, wholesale etc.) increasingly want same licensed capacity bands e.g. TDD 3.5 GHz
5. Congestion points – access in 5 GHz, backhaul in microwave bands
6. Opportunities in millimeter wave but immature regulatory framework and ecosystem
7. Lower frequency bands, e.g. 1.4 GHz provide good resilience against weather-related propagation effects but are being lost to other applications.
8. Capacity boost enabled by ever-wider channels but puts pressure on spectrum even above 6 GHz
9. Some sharing already, pressure for more to increase usage
10. More efficient spectrum usage requires relaxation of planning rules (for small cells) and of regulation for access to masts, dark fibre

3.11 Amateur radio

Sector scope: A wide range of applications, all of which use designated frequency bands for strictly non-commercial activities. Radio amateurs are licensed based on their passing certain tests, and despite their non-commercial activities may be as experienced and well trained as professional radio users.

Pinch-points:

1. The main issue in most areas of the spectrum is interference, especially as many AR communications use weak signals
2. In HF and VHF congestion has reduced due to lower demand from other users, although noise floors continue to increase.
3. In UHF and higher bands congestion is increasing due to greater amateur usage from digital repeaters, demands from defence usage and loss of spectrum to commercial users.
4. The RSGB believes current AR primary allocations are insufficient and there are no primary allocations between 400 MHz and 24 GHz, threatening confidence, investment and growth in AR.The problem is greatest for satellite transponders, EME and narrowband terrestrial systems.
5. Additional spectrum is needed to relieve digital voice congestion, enable new technology experimentation, introduce and extend digital TV, introduce new data modes and higher speed data technologies and to continue to enable the UK's lead in small satellites

4. Common themes

While some of the spectrum challenges faced by users are particular to one sector, we have noted a number of common themes, where positive action could benefit multiple sectors at once. Moreover, in some cases benefits would result from aggregating their needs together into a common approach with greater weight and purchasing power. These common themes are summarised below:

a) LTE in non-public applications: interest is growing in sectors such as emergency services, utilities and others. While technical mechanisms exist for such applications to share networks with public mobile traffic, progress is significantly hampered by real concerns regarding security, resilience and differing investment priorities and timescales.
b) Wi-Fi & LTE, individually and collectively, support an increasingly wide range of applications and create significant value, but create a perceived risk of crowding out other diverse but valuable uses which are individually lower profile but collectively bring enormous value, such as industrial short range applications.
c) Signs of an emerging new spectrum crunch in bands above 10 GHz: with 5G access, cell site backhaul, and wider Wi-Fi channels in this range, there may be jostling for position relative to established satellite, radar and fixed link applications. International considerations will be critical in this debate.
d) Spectrum sharing in its many forms remains critical but unsolved: although there have been developments such as geo-location databases, the tension between flexible access for new usage, protection for incumbent usage and its foreseen expansion and the need for all to offer assured services hampers progress and a more comprehensive spectrum sharing framework may be needed.
e) Many competing demands for sub-GHz spectrum – M2M networks for many purposes in unlicensed ISM, licensed 800 MHz, 700 MHz guard bands. All these may experience congestion. Broadcast and PMSE industry fear second digital dividend may be a cut too far when millions of homes continue to rely on terrestrial broadcasts for TV and radio.

f) Need for security and complete reliability applies to more services than in the past which has impact on the type of spectrum needed e.g. some PMR or M2M applications which have been ‘nice to have’ are now mission or even life critical so need more protected spectrum. For example, data services are becoming critical to emergency services whereas only voice used to be considered critical.
g) Emerging use of new devices which may have their own spectrum demands e.g. separate frequencies for remotely piloted aircraft, space planes, balloons, nanosats and new defence technologies.
h) Government targets for mobile broadband capacity – are these leaving insufficient headroom for other sectors to cope with an unexpected new requirement such as those arising from the increased defence use of drones and other technology[3] or the foreseen introduction of new systems in internationally harmonised bands?
i) Spectrum pricing can affect ability to use – mobile spectrum is often priced more highly and there is a call for uniform pricing especially in < 1 GHz, while on the other hand introduction of spectrum pricing for broadcasting would impact public service broadcasters’ ability to fund programming.
j) In some areas like public mobile and fixed wireless, site rental and other regulatory models are as important as spectrum itself in restricting usage – especially by limiting the reuse of cellular spectrum via small cells.
k) Difficulty of planning for spectrum needs of technologies which are little understood e.g. aerospace and defence technologies have long development times, and their spectrum needs are not yet fully understood, but may be mission critical. i.e. moves to share spectrum now may create problems in the future e.g. limit the number of planes that can be safely landed.
l) Clash between national spectrum release programme and the need of some users to operate globally in harmonized spectrum e.g. aviation and maritime
m) Many new data networks for vertical sectors are in LTE (LTE-R, emergency services etc.) – pressure on LTE spectrum bands esp. for coverage-oriented or M2M uses, but also an opportunity to aggregate demand for greater efficiency.
n) Post-TETRA situation – orange light users e.g. London Underground question what will succeed TETRA if they are left out of ESN
o) 5 GHz is becoming a very controversial band with Wi-Fi, other SRD (eg industrial control) satellite and LTE involved. LTE-U too late to the party?

5. The Spectrum Policy Forum Strategy and Priorities

The purpose of the Spectrum Policy Forum is to be a pro-active industry-led ‘sounding board’ to UK Government and Ofcom on future policy and approaches on spectrum and a cross-industry ‘agent’ for promoting the role of spectrum in society and the maximisation of its economic and social value to the UK.

[3] *“The UK should spend more cash on Special Forces and aerial drones to combat the threat of so-called Islamic State militants, David Cameron has told Defence chiefs”.* Source ITV News 13 Jul 15.

Its long term goals are to maximise the contribution of spectrum to UK ambitions on economic growth and societal improvements by:

- highlighting the inherent (and sometimes hidden) contribution of spectrum to the economy – in particular its role in tackling the big challenges facing society in the next 10-15 years
- facilitating innovation in (access to and use of) spectrum
- updating the framework for socioeconomic valuation of spectrum
- opening up millimetre wave bands for greater commercial exploitation
- enabling greater access to public sector spectrum
- enabling more spectrum sharing (including licence-exempt bands) by bringing greater understanding of the scope, obstacles and incentives for sharing.

The Steering Board maintains and continually evolves a workplan to deliver this strategy. During 2015/16 we are focusing on:

- Positive influence on UK position in EU and ITU
- Engage new Government Ministers to ensure spectrum remains high on their agenda
- Progress long-term goals

We will be updating the workplan to address the pinch points and common themes identified in this report.

6. Sectoral summaries

This section provides 'at a glance' summaries of the current and future status and spectrum usage of each sector. Subsequent chapters provide the details.

Quick links to each sector:

- Public mobile
- Utilities
- Business Radio
- Space
- Meteorology
- Defence
- Transportation
- Broadcasting and Entertainment
- Short range wireless
- Fixed Wireless: Access and Transport Networks
- Amateur radio

Public Mobile	
Scope of sector	Operators providing voice, text and data services over wireless mobile networks
Contributions to social and economic value	Mobile retail revenues were £15.6bn in 2013. Consumer surplus was estimated to be between £24.2bn and £28.2bn in 2011, with producer surplus estimated to be about £5.9bn. For 2012-21, the net present value of direct welfare benefits from mobile is estimated to be between £273bn and £341bn.
Current and recent past status	Major growth in mobile demand since 2008, fuelled by huge increases in use of mobile data, e.g. O2 customer data increase of 60% in 12 months Rapid uptake of 3G and more recently 4G/LTE Market subject to rapid change, involving substantial network sharing arrangements to invest in technology cost-effectively, consolidation and expansion, convergence between fixed and mobile and the emergence of multi-play offers in the market, competition from large MVNOs and operators using new business models e.g. OTT players
Sector trends	MNOs gearing up in anticipation of continued growth in demand Mobile networks are carrying increasingly asymmetric data traffic, with data downlink representing an increasing share of total traffic on mobile networks Increase in cell sites per network In addition to their increasing the capacity and sophistication of their radio access networks, MNOs require an expansion of backhaul capacity (both wired and wireless) to meet demand MNOs face an investment challenge to support rising data demands in the context of static or declining customer revenue Wi-Fi presents both a beneficial feature for mobile networks, offering

Public Mobile	
	capacity relief, and a challenge and mobile traffic is carried on frequencies that are out of operators' direct control
Spectrum usage	Current allocations in 800, 900, 1400, 1800, 2100, 2600 and 3500 MHz bands. The bands allow for liberalised use but, owing to legacy issues, carry traffic using a different balance of 2G, 3G and 4G across bands Recent re-purposing of 1400 MHz band for supplementary downlink, the first band of its kind to have this type of allocation. This was followed by a trade of this spectrum, the first mobile trade to fully test mobile spectrum trading procedures Different categories of spectrum usable for mobile face different use cases and different key issues: • There is a very limited amount of further sub-1GHz spectrum that can be made available for cost-effective UK-wide coverage and M2M applications; • There is more spectrum between 1GHz and 6GHz that may be made available for different uses within mobile networks; however, given that a disproportionate share of increases in mobile spectrum demand will likely be met from these bands, for both macro capacity and small cells, this spectrum will become scarce in the mid to medium term; Above 6 GHz is the key focus area for identifying large blocks of contiguous frequencies for 5G.
Expected technology & spectrum changes	Overall, evolution of mobile networks in the coming years will involve: • Evolution of LTE technology and networks to support wider range of IoT applications. • An increase in mobile cloud traffic, with the share of cloud-based data traffic forecast to grow from 35% in 2013 to around 70% by 2020. • The rise of heterogeneous networks based on small cells, flexible architectures and virtualisation. • Increasing use of TDD in new spectrum bands to address the increasing asymmetry of data traffic • Carrier aggregation to make use of spectrum in multiple spectrum bands as a single usable block, increasing average user speeds and making better use of smaller spectrum slices. However increased device complexity needs careful consideration. • Undertaking the challenge of re-farming of 2G and 3G spectrum despite the issue of legacy devices. • Tightening integration between licensed and licence-exempt spectrum and technologies, e.g. LTE/Wi-Fi Link Aggregation (LWA), LAA-LTE and LTE-U Ofcom is preparing for the auction of public sector spectrum in the 2.3

Public Mobile	
	GHz and 3.4 GHz bands in 2016 and plans later release of 700 MHz from current terrestrial TV usage for use by 2022. Other bands for future release in Ofcom's mobile data strategy include 1 427-1 452 MHz, 2 GHz MSS and 3.6-3.8 GHz. Other potential bands with greater uncertainty include 2.7 – 2.9 GHz, 3.8 – 4.2 GHz and 1 492 – 1 518 MHz.
Long term needs and options	With the emergence of heterogeneous networks and the growth of mobile traffic in different areas at different rates, there will be increasing scope for spectrum sharing, both by mobile spectrum users sharing with others and sharing of others' spectrum in defined areas. There are a number of key issues that will pave the way for a step change in the incidence of sharing: • There needs to be easy identification of sharing opportunities, in particular, through the creation of a central public sector spectrum database that is dynamic and in due course accessible to the market. • A balance needs to be struck between the flexibility foregone by spectrum licensees and the certainty required by those seeking to share spectrum to make the investments necessary to make spectrum sharing a viable business option. • For the net benefit of spectrum sharing to be positive, costs of sharing need to be low. This has implications both for the regulatory regime and for enforcement of contractual rights, both by spectrum licensees and by sharers. Universal pricing of spectrum across users is a key issue Usage of 700 MHz frequencies might be very different from their patterns in the early LTE bands - the new spectrum could be part of new '5G' network deployments, or could be reserved for specific services, such as internet of things applications, rather than for mainstream consumer data. Licence conditions must have the flexibility to use this spectrum most efficiently, subject to meeting interference criteria. 5G will also demand larger allocations of contiguous spectrum in bands in the 6 GHz to 100 GHz range. Harmonization is particularly important in higher bands because there is a tighter link between the technology and the use of the spectrum.

Utilities	
Scope of sector	Organizations supporting the generation, transmission and distribution of gas and electricity, excluding retail supply; the supply of water plus flood controls; waste water and sewage disposal.

Utilities	
Contributions to social and economic value	Massive social value of clean water supply and reliable power. Electricity, in particular, supports a very wide range of activities and technologies. £24 billion in direct economic contribution from energy sector in 2012 plus £78 billion through the supply chain. Employs 125,000 people directly and 539,000 jobs in its supply chain. Invested £11.6 billion in 2012, about 10% of total UK investment. Total economic impact of water and sewerage - £15.2 billion.
Current and recent past status	Increased use of energy and water, rising expectations of cost and quality, but pressure on supply. Systems to use resources more efficiently are urgently needed. Main current wireless applications – PMR, SCADA, telemetry, voice. Intelligence to be added to networks (smart grid), which requires mission critical reliability and ubiquity.
Sector trends	Introduction of smart grid and smart water, which are heavily reliant on wireless from the inter-grid systems to the last mile (e.g. smart meter). Deep analytics for smart allocation of resources to guarantee supply and quality. Transition from centralized to distributed networks. Increased automation of supply and distribution.
Spectrum usage	JRC manages spectrum and planning for utilities. It manages 4 MHz of spectrum, 2 MHz for automation and PMR, 2 MHz for telemetry/telecommand. Its main spectrum is in 140 MHz; 148.5 MHz, 456 MHz/461 MHz; 457.50-458.50 MHz/463-464 MHz. Utilities also use fixed wireless in microwave bands and satellite to connect sites.
Expected technology & spectrum changes	Key objectives to modernize existing systems e.g. SCADA and phase in smart grid/smart water. UK smart meter communications governed by DECC – in 410-430 MHz in northern region/Scotland; public cellular supplemented by 800 MHz mesh in south/Wales. Important debate over whether public mobile network is appropriate for a smart grid supporting dynamic allocation of energy/water. In some countries MNOs are dedicating a portion of their spectrum/network. Smart grid has different needs e.g. ubiquity, high reliability, high security, relatively low data rates, upload-centric. That supports an argument for dedicated spectrum in UHF band. Under consideration at EC level, with issue of whether utilities should pay for it. EUTC proposal to EC focuses on small allocations in several bands – VHF for voice and rural (50-200 MHz); UHF (450-470 MHz) for SCADA; shared access in 870-876 MHz for mesh and meters; L-Band (1.5 GHz) for smart grid data and security.

Utilities	
	Supplemented by access to public microwave and satellite bands for connections to backbone or resilient backhaul. Utilities may be users of recently opened VHF 143-169 MHz spectrum and of future 700 MHz allocations. Unlicensed spectrum has a role esp 868 MHz mesh for meters and other end points.
Long term needs and options	Rising number of applications will run on the smart grid, with increasing use of big data analytics – pressure on capacity, security and availability. This creates rising pressure on licensed sub-GHz spectrum, in demand from many users – policy decisions in 700 MHz, 450 MHz, VHF will be important. Will require seamless IP platform integrating many technologies and spectrum bands. Vision of three-layer system – PMR; mission critical data (dedicated LTE or UNB); public LTE overlay for non-critical communications. Growth of Internet of Things – utilities will be second largest sector for M2M connections in UK by 2020. Not just meters but asset management, plant monitoring, smart clothing for specialist workers etc. In some areas utilities will help drive smart city initiatives. Relevant future bands for utility M2M use – VHF, lower UHF (400 MHz), 870-875.6 MHz, guard bands, the duplex gap in 700 MHz and 1400 MHz band.

Business Radio	
Scope of sector	A very diverse sector covering emergency services communications, maritime communications and PMR (private mobile radio) for a wide range of vertical markets. Some users outsource the management of their PMR system to third parties such as Airwave (emergency services) or Ambitalk (more general users) in a model known as PAMR (Public Access Mobile Radio), which is done through an opex model (monthly rental of radios). However the vast majority of PMR schemes today are capex-based, with the users owning their own terminals and infrastructure.
Contributions to social and economic value	Inherent social contribution of emergency services is enhanced by mobile communications e.g. may save 560 lives and £980m by allowing ambulances to respond more quickly. Many PMR services are critical to national infrastructure (keeping water flowing or airports functioning) and there would be a huge cost if they were not available. PMR generates commercial revenue and had a net economic benefit of £2.3 billion in 2011.

Business Radio	
	Huge range of applications are enabled by BR, with the beneficiaries being the users not the BR providers (e.g. insurance companies profit from reduction in burglaries). Health and safety or maybe legal requirement such as ports or railway stations where staff have to have a radio to work.
Current and recent past status	Emergency services have a single national network run by Airwave using TETRA in 2x5 MHz of 380–400 MHz, granted by the MoD until at least 2020. The Emergency Services Mobile Communications Programme is a programme to replace Airwave with a new Emergency Services Network (ESN) for broadband public safety services, running on commercial LTE, as Airwave deals expire between 2015 and 2020. BR licence numbers and the numbers of users per licence are increasing. The move to digital data will enable new services and users and raises concerns that licences will run out under current rules. Spectrum capacity in conurbations is becoming increasingly congested. Research suggests that voice communications can share as high as 6 users overlapping each other's coverage area on shared frequency. BR as part of the UHF Strategic Review (420MHz to 470MHz) might have dedicated voice and data spectrum.
Sector trends	The most important trend is the move to digital data, which will enable many new business models. However, many analogue PMR services still operate (e.g. London Buses). Ofcom is maintaining a technology neutral approach, market forces will determine if choice of analogue is removed for customers. Some industries such as utilities still investing in multi million pound analogue trunked networks, waiting for digital trunked to prove itself and nervous about being early adopters, support expected for the analogue systems for a minimum of ten years. Initial responses to Ofcom's UHF survey suggested that analogue is preferred by customers over digital. Common features of all BR services are ultra-reliability and ubiquitous coverage, since many services are mission critical, plus ultra-low latency and enhanced support for group working. That involves network characteristics which are not shared with public mobile eg peer-to-peer, D2D and point-to-multipoint connection for large groups; enhanced encryption. These have to be maintained as the networks move to digital, IP, data and broadband/wideband. The move to digital is accelerating and will enable many new services and use cases, indeed many radios in the UK are dual mode with the customer offered a choice of analogue or digital use. Data is becoming as critical as voice in some applications and data requirements are varied – e.g. police want video imaging, firefighters want motion sensors.

Business Radio	
	PMR is better than public mobile at supporting some key trends in usage and so is likely to grow: e.g. location awareness for apps like real time transport updates (BR is more ubiquitous); corporate mobile-first strategies (better coverage for remote field workers, may be cheaper). Other trends include emerging use of drones in ES and PMR applications; heightened security awareness increases PMR use (eg airport security staff). Telemetry applications have been in use for twenty years offering low data rate, low latency functionality
Spectrum usage	ES and PMR use is concentrated in the VHF and UHF bands, especially the higher reaches of both where there is the widest range of equipment, and best performance. Manufacturers not interested in UK only bands or spectrum below 136MHz for digital, however, still limited analogue requirement in Low Band for wide area services such as PAMR. ES's TETRA service is in 380 MHz and 395 MHz, managed by the MoD. Other bands are used for communications, video and telemetry, eg 1 677-1 685 MHz, 1 790-1 798 MHz, 2 302-2 310 MHz, 3 442-3 475 MHz, 8 400-8 460 MHz, 10.25-10.27 GHz, 10.36-10.4 GHz, and 24.05-24.15 GHz. Ofcom offers a range of channels for PMR, between 6.25 kHz and 25 kHz, with others assessed on request. The spectrum is lightly licensed and tradeable or in the case of Area Defined leasable, but only certain portions are available in each PMR band, making them quite fragmented. As UK is largest market in Europe manufacturers have learned to adapt equipment to meet UK needs. No digital equipment in Band III but plenty of spectrum, likewise with Low Band. Band One showing interest in telemetry from water industry and transport and consultation published regarding IoT use of Band One and Low Band spectrum[4]. Limited use of spectrum leasing, some dealers use as investment and sell access to frequency on time or geographic basis. Tend to charge Ofcom licence fee and then management charge on top. It is contractual between the licence holder and the person they lease to, Ofcom does not get involved
Expected technology &	Move to digital, data and mobile broadband likely to drive a shift from dedicated networks like TETRA to use of general IMT networks e.g. LTE,

[4] http://stakeholders.ofcom.org.uk/binaries/consultations/radio-spectrum-internet-of-things/summary/more_radio_spectrum_internet_of_things.pdf

Business Radio	
spectrum changes	mainly in sub-GHz spectrum, though private networks are always expected for some applications. Mission critical data/video traffic likely to exceed capacity available for current TETRA networks. Best economics are to use LTE standards and share spectrum with public services – but will that involve significant compromises in availability and reliability, even with priority access? BR may require dedicated spectrum. Possible that voice will always have to remain as fallback for data in critical applications. LTE standards under development for BR (e.g. support for group working) but several years away in 3GPP Release 13 or 14. ESN will require new regulations – MNO commitments to resilience and pricing; hardening of networks and over 99% availability; flexibility to support different uses from streaming video to low latency telemetry. More efficient technologies in BR are still outweighed by rising demand for data – a net loss of spectrum capacity is expected. This will be driven by rising use of broadband telemetry and new M2M services. Data services do not have to use exclusive spectrum but will require additional questions as part of the licensing process, e.g. regarding the polling rate which determines whether shared or exclusive channel can be assigned. Ofcom recognizes need for new BR spectrum, considering 6 MHz of VHF spectrum in the 143-169 MHz band for new PMR applications (it is being returned by ES). This is licensed by MCA, London Buses and WPD amongst others. Ofcom says there is “no obvious source” of new spectrum in UHF1 or UHF2 for PMR, therefore more effective use of the existing spectrum will be necessary. Possible measures include spectrum sharing, more users per channel from current value of 2 to 3 or 4, replanning UHF band, dynamic frequency selection, increased use of AIP to encourage efficient use. CEPT has set up Project Team 49, to specify high-speed data applications and their harmonised spectrum requirements. It estimates that a minimum of 2x10 MHz of spectrum is required for this purpose for PPDR (public protection and disaster relief) data functions. CEPT also has FM54 which Ofcom chairs on behalf of UK. This was focused on GSM-R but is now focusing on PMR.
Long term needs and options	The 700 MHz auction may be an opportunity for new ES spectrum, but it will be hotly contested.

Business Radio	
	Ofcom wants the WRC 2015 to leave flexibility for each country to decide whether to allocate a dedicated sub-band within 700 MHz for ES. It will support LTE as a delivery platform for PPDR in any IMT band, not just 700 MHz. Another important issue is the future of voice –whether VoLTE can support essential functions like P2T and migration issues from TETRA. Ofcom removed 450-470 MHz band from its work plan but some want it put back on the table for ES/BR, especially in IoT/M2M scenarios – and even down to 380 MHz if NATO support can be obtained. No interest from MNOs in cellular for UHF but yes to telemetry, propagation suits infrastructure use with licence exempt spectrum for indoor use. Low data rate, narrowband If Ofcom re-aligns UHF will allow spectrum for Emergency Services legacy use, additional spectrum for PMR, allocation for PMSE, Maritime, Scanning Telemetry, possible allocation for CNI requirements.

Space	
Scope of sector	Remote sensing, Science and exploration, Navigation and Communications services As well as communications, the space sector enables services in finance, agriculture, transport, defence, planning, public protection, disaster relief and a host of others.
Contributions to social and economic value	Satellites are helping us to understand and address climate change, provide essential communications and information support for our armed forces, and deliver urgent aid when natural disasters occur. Aggregate UK space turnover in 2012/13 was £11.8bn, growing on average 8.6% since 2008/09 – well ahead of the growth rate of UK GDP (1.5%). UK Space Innovation and Growth Strategy is targeting a fourfold growth in the sector by 2030. Of the estimated economic value of spectrum of £52 billion in 2011, satellite services accounted for 7% of this figure and broadcasting (including satellite) for 20% The sector also supports thousands of jobs as a direct result of its activities, with employee productivity more than four times the national average. About 40% of the world's commercial telecoms satellites include a significant element of UK manufacture.
Current and recent past status	While government investment in space has been squeezed since 2008, there has been sustained revenue growth in Earth observation, GPS-based navigation, rural and remote broadband internet access and

Space	
	mobile backhaul accelerated by the build-out of Wi-Fi and small cells in rural regions Over 1,000 satellites were operating at the end of 2012 (38% for commercial communications and 16% for government communication) While mobile satellite voice revenues are flat or slightly declining, data revenues rose by 5% in 2012 and broadband services are continuing to grow
Sector trends	Advanced direct-to-home TV services are developing with higher quality, resolution and interactivity Hybrid satellite and terrestrial networks are being combined to expand the range of services and redcuce3 costs *Commercial se*ctor pressures include alternative solutions in rural markets, improving costs for non-satellite TV solutions, consumer trends to over-the-top TV rather than broadcast and the rise of quad-play service bundles In the *science sector*, Earth Observation data at ever-greater levels of detail are increasing the market, with 3860 EO-related launches in the next decade compared with 164 in the previous one. Constellations of satellites working together will be more prominent during 2010-2020, opening up new markets based on climate, environmental stress and security. The UK is well-placed to lead in this area
Spectrum usage	The space sector requires most of the spectrum allocations to be on a worldwide basis so satellites can be deployed to serve global markets and benefit from economies of scale Spectrum allocations for space services have been fairly stable since the foundations were laid at a World Radio Conference in 1963. Most allocations are already shared with other radio services, with sharing arrangements made at national or regional level. Globally, space services have primary allocations totalling 30% of all sub-3 GHz spectrum, 65% of spectrum between 1 GHz and 10 GHz, and 82% of spectrum between 1 GHz and 100 GHz. However, only 3% is available on an exclusive basis for space/satellite services, and between 3 GHz and 10 GHz, no spectrum is allocated on an exclusive basis. The main global allocations for satellite services are P band (0.23-0.47 GHz), L band (1-2 GHz), S band (2-3 GHz), C band (3-7 GHz), X band (7-8 GHz), Ku band (10-15 GHz), Ka band (17.3-31.0 GHz), Q/V band (31-52 GHz), W band (75-110 GHz). However UK allocations differ in some respects from the international table. There is no FSS allocation at 3.4 GHz to 3.6 GHz, or at 14.5 GHz to 14.8 GHz, in the UK, for instance. Commercial satellite services depend on satellites operating in C band, L band, S band, Ku band and Ka band spectrum. The take up of Ka band is

Space	
	accelerating due to the wider bandwidths to support satellite broadband services and UK operators have made £3.4 bn of investment in Ka band systems Earth observation satellites require ever increasing bandwidths for data downlink, including permanent links at Ka band Radar systems such as the UK's NovaSAR uses the S-Band allocation of 3.1 to 3.3 GHz to deliver weather data at low prices, based o see funding provided by UK government.
Expected technology & spectrum changes	- More efficient use of lower frequency spectrum via multi-spotbeam/high gain satellite antennas - Increasing frequency reuse of the same spectrum by multiple satellites - Use of complementary ground components (either signal repeaters or cellular base stations) especially at S-band - Ongoing upgrade programmes for many commercial satellites, especially in the low frequency L and S bands. The replacement programme will extend the life of the fleets by more than 15 years. - Drastic performance increase thanks to HTS (High Throughput Satellites) with multibeams payload and improved frequency reuse techniques - L and S bands will be complemented by MSS services in the Ka band, if high bandwidth is required. 2x500MHz of Ka-band is exclusive to satellite - Hybrid Ku- / Ka-band services are being launched, known as SAT-IP Considerable evolution in earth observation. For instance, 164 EO satellites have been launched during the past decade and this number is expected to grow to 360. About 80% are optical, requiring significant downlink capacity. WRC-15 – almost half the C band (3.6-3.8 GHz) could disappear, but it is important for tropical areas and satellite feeder links due to its resilience. It is important to consider whether mobile and C band satellite services can coexist so that interference would not threaten the quality of satellite services and mobile networks would not sterilize large areas from future deployment of satellite terminals.
Long term needs and options	- ITU Resolution 673 recognizes that the use of spectrum by Earth observation applications has considerable societal and economic value and urges Administrations to protect Earth observation systems radio frequency requirements - Improvements in spectral efficiency, and the capacity of Ka-band, mean current ITU Region 1 allocations should be sufficient to support the expected services until at least 2025.

Space	

	- Interest in increasing use of the 17.7 - 19.7 GHz / 27.5 - 29.5 GHz band by Ka-band FSS systems, in bands also available for terrestrial P2P fixed services. This is technically challenging because of the density of fixed services in these bands.
	- Satellite could be a component of 5G, delivering very high data rate services in broadcast mode and high-capacity two-way broadband services for complementary coverage to terrestrial networks outside urban and suburban areas. Very small satellites will be good for remote 5G coverage though more sharing will be needed WRC-18 agenda item – nanosats want 2 MHz in UHF
	- There are several threats to specific space sector spectrum bands:
	  o Potential reduced utility of the C-Band because of the identification of these bands for broadband mobile access.
	  o Impact on Earth Observation SARs in 5350 MHz-5470 MHz if this is made an extension band for WLAN
	  o 1 400 – 1 427 MHz: unwanted emissions from adjacent allocations into this passive remote sensing band
	  o Potential interference from terrestrial IMT in and adjacent to 1 518-1 559 MHz as well as 1 980 – 2 010 MHz used by Inmarsat
	  o Satellite bands above 6 GHz (e.g. C-band, Ku-band and Ka-band) are threatened from proposals for IMT/5G spectrum identification
	  o There are also potential threats to 1 675 – 1 710 MHz bands (meteorological satellites), 2 025 – 2 110 MHz and 2 200 – 2 300 MHz (space research, EESS and space operation services)
	- Overall the FSS/MSS/BSS players aim to ensure the continued long-term availability of *existing* ITU primary allocated or co-primary allocated satellite spectrum to MSS, FSS and BSS in L, S, C, X, Ku, Ka and Q/V bands to enable the continued development of new innovative satellite systems. Also they seek access to new ITU allocations (primary or co-primary) including additional co-primary spectrum at X-band Ku-band and Ka-band for FSS use.
	Overall Earth Observation seeks X band EESS with an extended worldwide allocation up to 600 MHz by WRC 15 (A1.1.12), to provide higher resolution images in all weather conditions, and A proposal is to be made to WRC-15 (A1.1.11) to allocate the 7-8 GHz band to EESS Earth to Space for high rate payload control and data links given S band congestion. Also spectrum to meet the need for higher resolution and 4D (ie including time): such bandwidth requires an extension of the current EESS (active) allocation around 9 400 MHz by 600 MHz

Meteorology	
Scope of sector	Meteorology provides a wide range of weather forecast and warning services to the public, emergency responders, defence, aviation, industry and a range of other stakeholders across Government, underpinning the protection of life and property Almost all of the observational data that is received and used for meteorology involves the use of the radio spectrum, with examples including data from meteorological satellites, weather radar, radiosondes, ocean buoys and windprofilers - all of which are coordinated within internationally agreed spectrum bands
Contributions to social and economic value	A 2014 estimate suggests that the economic value resulting from the Public Weather Service was £614M compared to running costs of £83M per annum. The social benefits are expected to be many times this figure when considering contributions to issues such as climate change, military activity and human health. The installation of a new supercomputer supported by government investments of £97m is expected to lead to incremental socioeconomic benefits of ~£2Bn from meteorological services and advice over a five year period.
Current and recent past status	The Met Office is a Government Agency, (part of BIS as from summer 2011), prior to this we were under the ownership of MoD, and hence much of our historical access to Spectrum was through the MoD. There remains close liaison between MoD and Met Office to ensure we co-ordinate over spectrum frequencies to ensure that we do not cause one another interference.
Sector trends	The existing relatively modest requirement for spectrum is not anticipated to change greatly in the coming few years. Whilst there will be greater data volumes from planned satellite missions it is expected that technological advances will balancing out the increases in volumes of data would hope to have sufficient capacity within the current bands

Spectrum usage	- Weather radar is the only means available for the measurement of rainfall and associated flash flood risk in real-time over large areas and also in critical rapidly responding catchments in urban areas. The current UK weather Radar Network is operated at 5.6-5.65 GHz, but weather radar can be operated as networks in the radiolocation allocations at 2.7-2.9 GHz (S-band) and 5.35-5.46/5.6-5.65 GHz (C-band). Non-network weather radars can also be operated at 9.3-9.5 GHz (X-band).
	- Satellite remote sensing and downlink operations provide observations which are a critical data input to both operational forecaster and Numerical Weather Prediction (NWP) supercomputer modelling requirements. Some bands are protected by Ofcom under an award of RSA, whilst others fall under (e.g.) MOD-coordinated bands. Key bands include:
	    o 1690-1710 MHz (geostationary & polar-orbiting downlink data)
	    o 3600-4200 MHz (FSS EUMETCAST downlink)
	    o 7750-7900 MHz (polar-orbiting downlink data)

<table>
<tr><th>Meteorology</th><th></th></tr>
<tr><td></td><td>
8025-8215/8400 MHz (environmental satellite data downlink)
10.7-12.5 GHz (EUMETCAST downlink)
- Balloon-mounted radiosonde sensors collect and transmit temperature, wind and humidity data as they ascend through the atmosphere. As such, radiosondes are an important input to an accurate forecast and also used to verify NWP models. Met Office operates radiosondes in the range 403-406 MHz. The lower part of the band (401-403 MHz) is also used offshore by meteorological buoys for the uplink of maritime data to relay satellites
- Wind profilers are Doppler radars pointing vertically and off-axis to provide an important 3D data source on wind speed, direction and turbulence within the atmosphere. These can be at lower frequencies for applications in the higher atmosphere (troposphere/stratosphere; 46-64 MHz) and higher up the spectrum for lower-level remote sensing (boundary layer; 915-921 MHz, 1290-1295 MHz).
The ATDNet lightning detection system is operated at various sites in the UK and overseas in order to monitor lightning strikes in real-time over broad areas of the globe. The frequency band 8.3-11.3 kHz is allocated internationally for this.
</td></tr>
<tr><td>Expected technology & spectrum changes</td><td>
If access to vital spectrum were to be denied or re-allocated to other users, example areas of detriment could include:
Increasing levels of interference to some of our key observing capabilities such as license exempt devices in the weather radar band of 5.6-5.65 GHz give us concern that soon those capabilities will become redundant, thus rendering the UK vulnerable to the full impact of life threatening floods and storms.
loss of key bands for downlinks of satellite data into the supercomputer facilities at Exeter would set accuracy of weather forecasts back some 30 years or so, meaning that high profile weather events such as the St Jude's storm of Oct 2013 which was very well forecast several days in advance allowing emergency services to be prepared.
The impact of deterioration in NWP accuracy (by loss of access to spectrum bands which deliver vital wind and temperature profile information) would diminish the confidence in finely balanced weather events, such as the forecasting of storm surges in the North Sea.
</td></tr>
<tr><td>Long term needs and options</td><td>The Met Office sees little change in its spectrum requirements even in the longer term, we believe that increases in data volumes (from future satellite missions etc.) which would suggest the need for more spectrum are likely to be balanced by technological advances and improvements in efficiency</td></tr>
</table>

Meteorology	
	The Met Office is open in principle to releasing any spectrum no longer required such as 137-138MHz which is no longer used in the UK by the Met Office.

Defence	
Scope of sector	The defence sector consists of the armed forces, including visiting armed forces, under the auspices of the Ministry of Defence, as well as all their suppliers and contractors. Activities include systems and operations on land, sea, air and space.
Contributions to social and economic value	The socio-economic contributions are to defend national security, economic stability and making a significantly contribution to the UK's export sales. Defence is also an important UK industry in its own right. The MoD has an annual budget of £14 billion for defence equipment and support, a significant percentage of which is spent with UK companies. The MoD and armed forces employ almost 200,000 people and the defence industry over 100,000 plus a further 145,000 in the supply chain. The sector's turnover is £22 billion a year.
Current and recent past status	The period since the end of the Cold War has been one of profound change in terms of perceived global threats; approaches to warfare and security; and the use of new technologies. Particularly since 2008, there has been considerable pressure on the UK defence budget, despite rising real-world and cyber threats and several active military engagements. These factors have led to greater sharing of resources with allies and investigation of how technology and artificial intelligence can achieve defence goals at lower cost (financial and human).
Sector trends	Rising reliance on wireless communications and surveillance, and on automated systems (UAVs, robotics etc). The rise of 'smart defence', which relies on IT and big data systems to identify threats and allocate resources intelligently, and uses deep learning as a source of intelligence. Increasing focus on cyber security and cyber defence operations. Greater reliance on information superiority and ISTAR (intelligence, surveillance, target acquisition and reconnaissance), which is heavily dependent on connectivity and real time data communications. Effectively, less troops equates to more capable technology leading to a greater reliance on the electromagnetic spectrum. Continuing cost pressures.
Spectrum usage	The MoD is the largest spectrum manager in the UK in its own right (about 35% of the FAT), and many players in the sector also use other spectrum including private and public. Conversely, other users both

Defence	
	private and public use MOD spectrum. It should be noted that around 85% of Defence managed spectrum is shared with somebody. Defence use of spectrum is extremely varied eg electronic warfare, or a large platform, such as an aircraft carrier, can involve a large number of wireless applications in different bands. Radio underpins many activities within C4ISTAR (Command, Control, Communications, Computers, Information, Surveillance, Targeting, Acquisition and Reconnaissance), the technology basis of all defence operations. Defence use of spectrum ranges from LF (30-300 kHz) for submarines, to millimeter wave (weapons guidance), plus many applications in UHF and VHF. Radar is the biggest single user – 25% of all military spectrum. Defence also uses public and third party spectrum. The defence industry also has specialised needs for spectrum, especially to develop and test equipment from electronic warfare platforms to aircraft.
Expected technology & spectrum changes	Key trends – diversifying uses of spectrum combined with pressure to share more. Information Superiority initiatives will increasingly rely on wireless connectivity. Unmanned weapons, robots and cyber-warfare will require new spectrum. HMG wants to spend more on UAV etc. to rely more on technology rather than troops but these drones will need “a fair amount of spectrum” to avoid mission failure and loss of life. World Radio Conference Agenda Item 1.5 covers a wide range of potential airborne frequencies. But there is a question as to whether the situation is safe according to ICAO. New wireless networks will be needed to support more agile C4ISTAR systems; cope with lower staffing levels; support rising traffic generated by new intelligence gathering and other applications; support the Land Environment tactical communications system. Increased pressure to use spectrum more efficiently to reduce costs, and to free up or share spectrum to support government mobile programmes. This is more about sharing than releasing spectrum. The MoD shares spectrum in various ways e.g. primacy for other services in 2 025 MHz – 2 070 MHz band; PMSE is secondary user of some MoD spectrum. This example gave industry the security of tenure it needed so it could invest in new technology to make full use of the band. MoD is to release 190 MHz of spectrum - 40 MHz in the 2.3 GHz band; 150 MHz in the 3.4 GHz band, above 3410 MHz and below 3600 MHz.

Defence	
	MoD has also released spectrum in the 870-872 MHz/915-917 MHz band for licence exempt SRD and IoT. In November 2011, the MoD also outlined plans to open up some of its bands for sharing with public or private sector organisations (updated in December 2012) and a review process is ongoing. Sharing spectrum without compromising defence activities will require mechanisms such as geolocation databases, cognitive radios etc (work ongoing). These may not have to be complicated technology e.g. simpler mechanisms around geographical sharing can be safer. Due to the difficulties in Defence releasing additional spectrum, the focus has moved to sharing. Defence must fully understand and agree the terms before allowing sharing in military managed spectrum.
Long term needs and options	Likely to be increased pressure to use spectrum more efficiently, especially for radar. Caution is needed because spectrum could become a battle space in its own right, as unmanned and cyber technologies take centre stage, and warfare becomes 'virtual'. Lack of clarity over precisely how emerging technologies, like ultra-precise weaponry, will use spectrum. Cost savings/budget reductions are being achieved by the draw-down in military personnel. This places an increased reliance on technology to provide the winning edge for defence. Given the governments (PMs) clear direction that an increased number of "Drones" that will be needed this will continue to drive MOD's need for sufficient spectrum to conduct ISTAR operations to achieve Information Superiority.

Transportation	
Scope of sector	Services and equipment for carrying goods and people on aircraft (private and commercial), trains, metro/city transportation systems, ships (including fishing), and road vehicles. All of these either are, or becoming increasingly dependent on wireless connections for communications, customer services, navigation, knowledge of aircraft / ship location, security and safety, and automated control and customer (passenger) services. A commercial jet, for instance, has about 30 antennas supporting safety of life applications. Transport, particularly in the aviation and maritime areas, relies on globally harmonised spectrum and interoperable systems and areas such as trains are increasingly looking towards at least regional interoperability, for example for cross European services. In order to

Transportation	
	provide safe integration and interoperability, transport spectrum, particularly aeronautical, is also utilized by defence.
Contributions to social and economic value	Transport is a significant contributor to the UK economy: the aviation industry accounts for about 4% of GDP or £64.5 billion. The railway sector employs 212,000 people and its tax contribution, of £3.9 billion in 2013, offsets government funding for the industry almost precisely. It delivers £13 billion a year in benefits to passengers and freight users, and £10 billion of additional GDP through its supply chain and impact on stimulating other economic activity. The maritime industry makes a direct contribution to the UK economy of between £8 billion and £13 billion, according to 2013 government figures. More than 90% of global trade is carried by ship, and 99% of UK trade by weight. As well as contributing directly to the economy, the transport industries stimulate productivity and GDP increases in other sectors by enabling greater efficiency. For instance, at the start of the Crossrail railway project, the GDP benefit for the UK was estimated at £20 billion and the welfare/social impact benefit at £19.9 billion – many of those benefits resulting from shorter journey times.
Current and recent past status	The requirement for all kinds of transport has grown steadily along with key trends such as increased consumer spending, urbanisation, rise in international travel and the rise in car ownership.
Sector trends	In most areas of transport, there are growing numbers of routes as well as passengers, requiring larger or more complex wireless management systems (new railway and Tube lines, airline and bus routes). For instance, an increasing number of train lines now use in-cab signalling or ETCS. Expansion of the systems can also raise safety concerns, driving investment in wireless technologies which can reduce risk, often based on radar (anti-collision systems for aircraft, cars and buses, for instance). Passengers demand new services such as on-board Wi-Fi and real time travel updates, and freight customers also want to be able to track their consignments at all times. Transport operators in competitive areas like passenger flights or cross-Channel links are always under pressure to improve customer satisfaction and increasingly that revolves around mobile apps and information. Government agencies also harness technology to improve satisfaction levels to justify tax support for transport, and to introduce efficiencies such as NFC-based ticketing (on London transport and elsewhere). 'Smart transport' systems use many types of sensors to monitor fuel efficiency, traffic patterns and so on, and to automate formerly manual processes, the eventual endpoint perhaps being the driverless vehicle (already here in light railways and drones, a distant prospect in passenger aircraft). Transport is an important element of any smart city project.

Transportation	
	However, there are significant barriers to adopting new technologies rapidly in the transport sector, especially when it is international, because of the need for global consistency. Infrastructure takes many years to plan and build, safety testing is rigorous, the environment is heavily regulated and retrofitting is costly especially when considering cost of downtime. For example, aviation is governed by at least eight international agencies, alliances and standards bodies.
Spectrum usage	**Aviation** Frequencies in use by aircraft range from 200 kHz to 100 GHz. Services include: Air-to-ground communications in MF, HF and VHF bands plus satellite. Ground-based navigation systems received at the aircraft such as beacons and landing systems, supplemented by satellite. Ground-based radar for air traffic control support and to monitor movements around airports, in the L-, S-, X- and Ku- bands. Airborne applications include safety (e.g. weather radar, altimeters, distress and safety systems) and non-safety for passenger use (e.g. in-flight communications, in-flight broadband). **Rail**: Fragmented older systems for train-to-track communications are being replaced with GSM-R which is mandated at EU-level and operates in dedicated spectrum in the 900 MHz band. Legacy systems are being phased out including the National Radio Network (in 200 MHz), Cab Secure Radio (in 450 MHz) and the Radio Electronic Block (in 200 MHz). In-cab signalling is also an important application and trains are starting to feature more passenger wireless services, such as in-train Wi-Fi (which may be backhauled by cellular or satellite). The London Underground has particular communications needs to link its stations and trains (some of them driverless), and has its own Airwave Tetra network for communications to its 125 below-ground stations, and for emergency response. **Maritime:** Ships of all kinds use spectrum for a wide variety of purposes, many of them mission critical and some internationally harmonised. Assignments for shore-based services are carried out on a national basis by Ofcom, and a ship's one-off lifetime licence covers all maritime radio systems. Maritime radar often operates in spectrum shared with the CAA and MoD. Radio communications in the low frequency UHF and VHF bands are particularly important for penetrating ship elements like the bulkhead while keeping them water-tight. There have been problems in some ports in states where UHF spectrum has been released to other users. It is also becoming increasingly difficult to make new VHF assignments to ports. The maritime sector continues to roll out additional functions within the IMO's GMDS (Global Maritime Distress and Safety System), which will be in use for at least another two decades. Key elements include the EPIRB (emergency position-indicating radio beacon) in 406 MHz, the Navtex information broadcast system in 519 kHz, Inmarsat C satellite services and others. **Road**: While private vehicles have not generally needed dedicated spectrum, this will change with the rise of smart transport, often within smart city programmes; and intelligent vehicles. These may lead to

Transportation	
	needs for dedicated frequencies, and/or put increased pressure on existing licensed and licence-exempt bands. Currently the heaviest road users of dedicated spectrum are the bus networks, especially in London, which has 9,000 buses. The main wireless network connecting all these elements is the MPT 1327 analogue trunking radiocomms network, powered by 10 radio sites and 66 traffic channels.
Expected technology & spectrum changes	**Aviation** use of wireless will continue to increase, leading to increasing sharing between aviation systems. The CAA are leading studies into more efficient use of the 2.7-2.9 GHz band that could facilitate release of spectrum for mobile; broadband in the 2016-2020 timeframe. Possibilities being considered are retuning radars to operate in the upper end of the band, or in 2.9-3.1 GHz, replacement of existing radars with new technologies or sharing with other government services thus releasing spectrum in another frequency band. Wireless avionics will drive additional usage of existing allocations of spectrum. New uses of radar include plans to use radar on aircraft wing-tips, which may involve the reuse of spectrum supporting automotive radar. To address rising congestion in VHF bands, aircraft are being fitted with 8.33 kHz rather than 25 kHz narrowband VHF radios. There is however some discussion about long term (2040+) updating and rationalisation of aeronautical systems which as a bi-product may release spectrum currently used by aviation however this will require International agreement and action. **Railways** have an eventual goal to use radio systems to replace lineside telephones to avoid issues from wire theft and increase reliability. There is increasing use of machine-to-machine technologies for purposes such as monitoring conditions in the train, but little availability of equipment in the GSM-R band, which limits the economics. GSM-R will become universal and GPRS will be added to increase its functionality. There will be increasing use of gateways on trains to support Wi-Fi or cellular services for passengers. In the London Underground the TETRA network will need replacement, potentially using LTE, however deep coverage well beyond existing public networks needs to be provided for this challenging environment. LUL wants to negotiate with Ofcom to receive additional spectrum which would support a wireless data network that would be effective in supporting data to and from underground and overground trains and stations, plus portable handheld devices, in-cab CCTV and other connected equipment. **Maritime** users are making an important transition to digital radio systems to create spectral efficiencies and support new services, notably E-navigation for decision support systems and 'single window'. However this may still not create enough capacity to avoid the need for new sub-1GHz spectrum allocations. There will also be additional service provision in GMDSS (global maritime distress and safety system), as well as improved, and increased, usage of on-board UHF

Transportation	
	communications. New radar technologies may yield greater spectrum efficiency. **Road** The existing communication system for London buses is in need of capacity upgrade to cope with the volume of calls made to meet increases in passenger demand and the need to meet more stringent targets on waiting times even in the face of major road infrastructure projects. Intelligent transport is seeing many developments. Much of this relies on public mobile or licence-exempt spectrum. Also IVI (in-vehicle infotainment) and other connected car services, some city-driven applications like smart parking, often using licence-exempt 868 MHz spectrum. Beyond this the Intelligent Transport System (ITS), designed to improve road safety, will start to use the European harmonised 5975-5905 MHz spectrum. This actually includes both licence-exempt usage (Safety-related, vehicle-based ITS applications) and licensed usage (safety-related ITS infrastructure, and non-vehicle installations). Most ITS has focused on a special variant of Wi-Fi, 802.11p or on an ETSI proposal for STDMA (self-organised time division multiple access). In either case, estimates suggest that more than 80 MHz of bandwidth would be required to achieve 99% reliability, far more than the 10 MHz set aside in Europe and the US.
Long term needs and options	**Aviation** is currently working on a global aeronautical distress & safety system intended to improve on a global basis, especially in remote and oceanic areas, the monitor and in times of distress reporting of aircraft locations. Additionally work is ongoing to understand what the air traffic management systems of the future (2050+) might look like given the development cycle and lifespan of aircraft, and how the number of current systems might be rationalised. Remotely piloted aircraft are expect to need 150 MHz of additional spectrum for reliable command and communication. On the way to that goal, intermediate steps such as higher levels of automation within conventional aircraft and air traffic management, reducing the number of pilots per plane; and the use of small commercial drones will drive progressively towards that level of spectrum requirement. The advent of space planes operating up to an altitude of approximately 120 km presents a new challenge to the spectrum world as they are beyond what would be perceived as a terrestrial service, but below that for satellite What spectrum is appropriate will require more studies into propagation, interference risks among other issues. Mesh networking between aircraft, where aircraft act as nodes and create ad hoc wireless networks in the sky, could act as a partial alternative to satellite communications. Spectrum availability will be key in supporting the systems necessary to achieve the goal of operating manned and unmanned aircraft in unsegregated airspace. The advent of space planes at around 120 km altitude puts them above terrestrial, but below satellite altitude. It is possible that astronomy or space research bands might be appropriate, but far more studies are needed of propagation, interference risk and

Transportation	
	other aspects. The primary issue is how to classify them since they have both terrestrial and space modes. Mesh networking between aircraft, where aircraft act as nodes and create ad hoc wireless networks in the sky, could act as a partial alternative to satellite communications. **Railways** While GSM-R is only just becoming ubiquitous, it is likely to become obsolete by 2024 and a replacement roadmap is not yet clear. The trade-offs between the pain and risk of migrating a huge and critical system, and the benefits of more modern technology, have to be closely assessed. LTE is being discussed, but in some views a dedicated 'LTE-R' network would require new spectrum - one suggestion is that spectrum adjacent to GSM-R (872-876 MHz paired with 917-921 MHz), might be allocated in future, or alternatively some of the frequencies in the hotly contested 700 MHz broadcast band, when that is freed up around 2018-2020; or options in 400 MHz. However, at least 10 MHz of spectrum would be needed. Sharing with commercial traffic would only be possible if key conditions on reliability, availability, cost, technical capabilities and European-level acceptance of putting a public safety network in commercial hands. However, while data is increasingly critical, voice will become less critical and could be run on the public networks in future. Regardless of spectrum/network choices, there is likely to be development of the radio technology as ETCS becomes increasingly central to railway safety and efficiency – on the wishlist is an ETCS-optimised, ultra-robust radio delivering 10-20kbps at speeds of 500 kilometres per hour. **Road** Networks for bus and other road transport may increasingly make use of LTE as new features and operator SLAs evolve. In the medium to long term, commercial LTE networks could be the primary ones for data, and the fallback for voice. The biggest changes to road transport of all kinds will be driven by smart transport and connected vehicles developments. Vehicles will be equipped with rising numbers of sensors in order to communicate automatically with one another, with central management systems, with roadside infrastructure and with the internet.

Broadcasting and Entertainment	
Scope of sector	Broadcasters delivering radio or TV programming over terrestrial radio networks (digital terrestrial TV or DTT) - mobile and satellite delivery of TV is addressed in the relevant chapters. In the UK, DTT channels are broadcast by over 100 providers, the majority of them free-to-air, using the DVB-T/T2 technology (largely HD) and the Freeview service. Players include BBC, BT TV, C4/S4C, Five, ITV, Sky, and UKTV.

Broadcasting and Entertainment	
	The UK has one of the world's largest DAB digital radio networks (c250 commercial stations plus 34 BBC stations) and over 540 analogue radio stations, mainly in the FM band (as of 2012). This sector also includes the PMSE (programme making and special events) segment. This contains providers and operators of audio equipment for public events and live content creation, mainly wireless microphones and in-ear monitors as well as wireless cameras and video links critical to a wide range of programme making functions including newsgathering, sports and coverage of live events.
Contributions to social and economic value	The UK TV industry generated £13.2 billion in revenue in 2014, and 92% of people watch TV each week, down slightly from 93% in 2013. Over a five-year period, TV industry revenues have experienced a compound annual growth rate of 2.8%. Revenues are growing driven by Freeview, multiple TV screens per household, HDTV. TV drives revenues for other sectors such as advertising; content production and distribution; sports; books and music; equipment. The total broadcasting value chain supports at least 40,000 UK jobs. TV and radio generate significant social value in terms of affordable entertainment, education and information; universal availability of news and analysis of current affairs; the ability to bring mass audiences together for major events of national and global significance. Broadcasting emerges as the second largest component of the total economic value of UK spectrum (after public mobile), at £10.8 billion (as of the end of 2011, according to Analysys Mason). PMSE is an enabler of a creative sector with £71.4 billion in revenues which employs 150,000 people. It enables high quality content and experiences which benefit all citizens and is essential to the film and TV programme-making process.
Current and recent past status	Significant change since digital switchover in viewing habits, number of channels, introduction of HDTV. TV and some radio have transitioned to digital. Free to air services include the Freeview, Freeview+ and Freeview HD brands on DTT. Freeview was the first operational TV service in the world to use the DVB-T2 standard, which allows more efficient use of spectrum and was one of several enablers for the launch of HD services. There are several TV platforms serving the UK, the Freeview platform based on DTT remains the single largest viewing platform but alongside

Broadcasting and Entertainment	
	strong demand for Pay-TV (cable, IPTV and satellite) OTT providers (e.g. Now TV, Netflix and Amazon) and the growth of video on demand. DTT is underpinned by eight active multiplexes, three carrying the free public service channels of BBC, ITV, C4/S4C and Five, three for commercial broadcasting. There are also three further more recent multiplexes, two of which are interim muxes using DVB-T2 and carrying mainly HD services and one carrying local TV services.
Sector trends	There is rising use of connected TV services, which deliver VoD and catch-up content over the internet, to PCs, smart TVs or mobile devices. Freeview's stakeholders have launched their own, free version, Freeview Play. However, broadcast TV still expected to account for 80% of viewing in 2020 (down from 92%) (source: Enders analysis). Broadcasters are already delivering content to mobile devices through existing networks and mobile operators are aiming to support further TV and VoD services e.g. with LTE Broadcast. For now however mobile viewing of live content remains very low. For **DTT** there is an increase in competition from both new content providers through pay-TV (e.g. Now TV, BT TV) and OTT (e.g. Netflix) and from alternative delivery networks. Content is increasingly being delivered through mobile and fixed IP networks, with free-to-air TV also being delivered over other methods e.g. FreeSat. Broader competition for consumers' time from non-TV video (e.g. YouTube), longer working hours, other leisure activities, digital or not. Questions of the rate at which revenues will be able to continue to grow when the boost from digitalisation and HD wears off. The transition of analogue radio to DAB is well behind the equivalent digitalisation of TV services. Currently it is unlikely that any decisions about this transition will be made before 2017 and Government has restated its commitment to revisit transition plans when a majority of listeners have adopted DAB.[5] For **PMSE** there is growing demand as producers and consumers raise their expectations of live content quality. For audio, live content is increasingly the leading revenue source for musicians/record labels and others and more sophisticated shows require larger numbers of microphones.

5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/270375/Digital_Radio_Action_Plan_v10__5_.pdf

Broadcasting and Entertainment	
Spectrum usage	Digital TV typically requires around fourteen times less spectrum to transmit an equivalent signal, compared to analogue (five or six times with HD). More channels and services can be supported, and the 800 MHz digital dividend enabled. The 800 MHz (790-862 MHz) band was auctioned for LTE use. Freeview spectrum was harmonised with Europe after the 800 MHz band was replanned in 2014, which meant moving DTT users out of channels 61 and 62 and into channels 39 and 40, and PMSE users in channel 69 down to channel 38. The 600 MHz band (550-606 MHz) was licensed on an interim basis to Arqiva for Freeview HD expansion in order to encourage HD take up via DTT.
Expected technology & spectrum changes	DTT and PMSE remain, for now in the whole UHF spectrum between 470 MHz and 790 MHz, but the 700 MHz band (694-790 MHz) will be allocated to mobile broadband between 2018 and 2020. To accommodate 700 MHz clearance DTT would need to be replanned in the 470- 694 MHz range, which also has to accommodate DVB-T2/MPEG-4 Freeview HD, PMSE and white space services. Arqiva's licences for the interim muxes in the 600 MHz band can run until 2026, but with a break clause which could be invoked as early as 31 December 2018. **DTT** The EU supports the Lamy Report proposal that says DTT access to sub 700MHz (470-694 MHz) should be 'safeguarded' until at least 2030 Further implementation of technologies to support HD content, interactive services and greater spectral efficiency, particularly DVB-T2 and MPEG4 compression, and 4K UHD may drive spectrum demand. Increased reliance on internet-delivered video and services, and mobile TV, to complement DTT. Some developments that suggest broadcast and wireless broadband services and spectrum may not need to be mutually exclusive as in the past, but the future of such technologies is uncertain at this stage. Spectral efficiency may be improved by moves from higher power multiple frequency networks, but the extent of any gains is disputed. **PMSE** BEIRG (the British Entertainment Industry Radio Group, which represents the PMSE sector), argues that the loss of the 800 MHz band,

Broadcasting and Entertainment	
	and the likely loss of 700 MHz, is creating significant uncertainty, which affects investment in PMSE equipment development. One of the spectrum issues for PMSE is that almost all (99.9%) of its equipment in the field is analogue. Digital PMSE equipment take up is likely to be very slow unless further development work is undertaken to minimise latency, improve battery consumption, improve warnings of link failure and offset the cost not only of the devices but also for studio equipment upgrades. EC proposals suggest a minimum of 60 MHz is made available for audio PMSE, but some studies indicate that busy cities or events may require over 100 MHz. Possible options are duplex gaps in the 800 MHz and 1800 MHz bands; sharing with mobile downlink and other services at 1427-1518 MHz; sharing in 960-1350 MHz and 1525-1710 MHz. PMSE bodies argue that in most cases they would be sharing with LTE, whose high out-of-band emissions could cause interference and a failure to meet QoS licensing mandates. Ofcom have commissioned sharing studies with regards to audio PMSE in the bands 960-1164 MHz (CAA band) and 1525-1559 MHz (MSS band). The results of these studies are expected very soon. At a European level two ECC/CEPT reports are looking into further sharing possibilities in the bands 1350-1400 MHz and 1492-1525 MHz. At time of writing the draft ECC Report 245 on 1350-1400 MHz has been adopted for public consultation by Working Group Spectrum Engineering (WG SE), the second draft report on 1492-1525 MHz has gone back to SE7 for further work. However, it should be noted that if none of these sharing options prove to be viable or achievable then audio PMSE will face severe problems, post any 700 MHz clearance. Video PMSE is also undergoing change with an expected move to 7 GHz and 2 GHz following auction of the 2.3 and 3.4 GHz bands. PMSE demand is predicted by the industry, to outpace the efficiencies achievable through new technology.
Long term needs and options	Many decisions about future platforms will be influenced by eventual UK and EU policy on the sub-700 MHz UHF spectrum. The Lamy report of September 2014 recommended that the lower UHF band (470-694 MHz) be retained for broadcasting until at least 2030. At the 2014 World Cup the BBC and partners trialled the first UK demonstration of over-the-air UHD, and the first trial of simultaneous distribution over DTT and IP. This demonstrated the possibility of converged UHD delivery for broadcast. By using HEVC technology the trial also demonstrated that spectrum efficiency gains can be achieved by the use of improved video compression technology.

Broadcasting and Entertainment	
	Hybrid approaches have been developing, such as HbbTV (hybrid broadcast broadband TV). Ofcom is supporting the broadcasters in their use of hybrid IP/free-to-air platforms. Rising use of IP – as seen in plans for Freeview Play – is one way to encourage audiences to take up connected services. LTE Broadcast and 5G successors become relevant technologies, shifting spectrum use to the mobile bands. DVB technologies are also evolving to support mobile consumption with activities like DVB-T2 Lite and DVB-NGH (next generation handheld) - fewer migration issues but less integration with mobile technology. An extreme view is that DTT will disappear by 2025 but it is highly unlikely the UK would achieve this without significant intervention by Government and the forced migration of millions of terrestrial TV homes to other technologies. One future option is a fully converged network – at infrastructure or platform level which might enable a single infrastructure (transmitters and backhaul) and spectrum band to support mobile services and broadcasting, with devices capable of receiving both types of content – broadcast and IP and enabling flexible spectrum use for linear and non-linear broadcast content, in broadcast (broadcasting), multicast (IPTV) or unicast (VoD) mode as required. However there are doubts as to the true extent of any spectral efficiencies and many technical and public policy issues mean this is unlikely to be achieved, if ever, until 2025 or later.

Short range wireless	
Scope of sector	This spans two rather distinct sets of technologies: Short Range Devices (SRDs) and Wi-Fi, with distinct user bases and applications. However they often the same share licence-exempt spectrum and their future evolution requires joint consideration.
Contributions to social and economic value	Wi-Fi has been an extraordinary success story in terms of global adoption and its rapidly expanding set of use cases. The embedding of Wi-Fi into billions of consumer devices, initially laptops and later handsets, cameras and tablets; and the creation of public access points or hotspots, to support broadband access on the move have particularly catalysed widespread adoption. Ongoing standards evolution is stretching Wi-Fi's functionality into new applications areas such as long range low power broadband, rural access and smart cities, sometimes involving new frequency bands, below 1 GHz and at or above 60 GHz. In

Short range wireless	
	2012, over 80% of smartphone-originated traffic in the UK ran over Wi-Fi rather than cellular and an even higher percentage when users are at home. One estimate suggests that the value of improving Wi-Fi's capacity and quality of service, through additional spectrum, would be worth €16.3bn to the EU economy. SRDs span a wide range of categories of use with important economic and social benefits, such as Industrial control and telemetry, Medical implants and medical body area networks, railway identification and vehicle-to-track communication, licence exempt radio microphones and much more besides. There is a risk of hidden consequences from spectrum changes which affect this sector as this diverse user base does not have a common voice. In one study, RFID, a particularly efficient SRD technology used for telemetry and smart barcoding, could contribute about £620 million per MHz to the UK economy over 20 years compared with broadcasting and mobile would each contribute less than £30 million. Much of the future contribution of SRDs will be related to the growth of the Internet of Things in unlicensed spectrum. By 2020, the economic potential of the IoT is calculated to be over $1.4 trillion a year, or five times the economic contribution of the Internet today, and unlicensed spectrum could support over 90% of the billions of devices which will be connected. This will have social benefits in terms of new services, smart cities, improved health monitoring and others, leading SRD sector lobbyists to suggest that their services would be a better economic use of additional spectrum in the 5 GHz band than expanded Wi-Fi capacity.
Current and recent past status	Wi-Fi traffic is expected to exceed wireline by 2020 and has already passed total cellular traffic. In the UK, mobile and Wi-Fi traffic will reach 88.6 petabytes in 2014 and grow to 445 petabytes in 2018, with at least 60% of this being carried over Wi-Fi. The 802.11 family of standards which underpin Wi-Fi has grown rapidly, with 12 mainstream additions to the 1997 specs either completed or in the works, plus extensions for specific purposes such as security (802.11i/WEP) and quality of service (802.11e). Some of the new extensions have been geared to increasing peak and average data rates, as well as range, to support broadband applications (802.11b, the first fully commercial version, boasted peaks of 11Mbps; now 802.11ac is being deployed commercially and supports gigabit-plus data rates; a future iteration, 802.11ax, aims to quadruple those speeds and provide better stadium-area coverage). However, rising speeds and usage are putting intense pressure on available spectrum capacity, risking a backlash against Wi-Fi if quality deteriorates as a result. SRDs face comparable growth challenges. Conservative estimates of devices sold annually in the EU for the 863-870 MHz band alone.
Sector trends	Increasing emphasis on higher quality of service (QoS) in Wi-Fi to support shifts to carioer-grade networks. This is being enabled by new

Short range wireless	
	specifications (e.g. as Next Generation Hotspot and Passpoint/HotSpot 2.0), integration of Wi-Fi into mobile- and fixed-operator networks and work on intelligent access control to provide the most appropriate connection for a given application at any given time. A wide range of SRD protocols are in place to suit different applications. These include as well as Bluetooth, ZigBee, 6 LoWPAN, Thread, Z-Wave, Ant+ and others. A large proportion of SRDs run proprietary technologies for ultra low power consumption and which avoid complexity from protocol stacks.
Spectrum usage	Both Wi-Fi and SRDs operate predominantly in licence-exempt spectrum. Wi-Fi uses 2.4 GHz spectrum extensively, where significant congestions limits performance in outdoor public locations and city centres. It supports only 3 distinct 20 MHz channels. 5GHz (5150- 5250 and 5470-5725 MHz) has eased congestion in the near term, but usage is increasing rapidly: For instance, on The Cloud's hotspots, 5 GHz usage started to rise significantly in 2013 and now accounts for two-thirds of the data, and 51% of the sessions, on the network. While 5 GHz supports 19 x 20 MHz channels, Wi-Fi increasingly uses channels as wide as 160 MHz with the latest 802.11ac technology and the split band means that only two contiguous 160 MHz channels are available. Portions of the lower band are also subject to dynamic frequency selection mechanisms to protect incumbent radar users, but which lead to significant performance degradation through 'false positives'. Poor indoor penetration limits congestion in 5 GHz somewhat – a lot of congestion comes from non-intelligent deployment of WiFi (eg SSID broadcasts filling up spectrum), so pressure for industry to address efficiency. SRDs also operate in 2.4 and 5 GHz, but also a range of additional bands such as: 433 MHz, 863-868 MHz, potentially UHF white spaces, 920 MHz, 2.48-2.5 GHz, 4 GHz, 5725-5875 MHz and 5875-5925 MHz. 60 and 77 GHz are also available. Although SRDs require limited bandwidth, there are still rising concerns over congestion due to the large number of devices planned for IoT applications. Although licence-exempt spectrum provides flexibility, there is a need to ensure quality of experience, especially for critical applications like transport safety, rescue helicopters or MBANs. In 77 GHz a 'tragedy of the commons' is threatened by uncoordinated usage by different groups. New control will be required because the band supports transport radars, which include car safety and air ambulance applications.
Expected technology & spectrum changes	To address the challenges seen in both Wi-Fi and SRDs, there are calls for categorising users according to relative transmit powers and duty cycles into different bands or sub-bands to improve compatibility.

Short range wireless	
	New spectrum may come from a range of sources: - Extension of the 5 GHz band which is happening elsewhere (e.g. the US) but is controversial in Europe - Expansion of the 863-870 MHz range to include 862-863, 870-7876 and 915-921 MHz, bringing Europe in line with US allocations and creating global harmonisation for applications like RFID. European SRD specifications are being extended accordingly. - The 5725-5825 MHz band is being examined by CEPT groups for large networks in environments such as factories - Sharing spectrum in other bands: TV white spaces is one example, supported by 802.11af for Wi-Fi like broadband applications and 802.11ah for lower bandwidth applications such as IoT. - Expansion of Wi-Fi into 60 GHz via the WiGig/802.11ad standard. Although the 60 GHz bands is very wide, with WiGig channels as wide as 2.16 GHz the number of channels is limited SRD devices in the form of radar sensors are likely to make further use of 77 GHz
Long term needs and options	- Higher frequency bands are under consideration for future SRDs, including 122 GHz for high resolution sensors and other general purpose devices (now a full proposal). The huge swathe of spectrum between 200 GHz and 600 GHz is the subject of an ITU proposal for intrachip communications - There are competing views on future spectrum policy for licence-exempt spectrum, with some advocating much broader and more liberal application of licence-exemption, while others favour a more regulated approach to band planning within LE spectrum to minimise congestion - There are tensions between the use of some bands, notably 5 GHz, with very different requirements between applications such as consumer access and industrial automation - 5GHz is also likely to see new usage from LTE-style technologies such as LAA-LTE and LTE-U which use 5 GHz and other licence-exempt bands, either in conjunction with licensed spectrum or in isolation which could further increase congestion

Fixed Wireless: Access and Transport Networks	
Scope of sector	The sector covers any services delivered over wireless networks with no mobility in the end points, primarily mobile backhaul, wireless broadband access, and private enterprise networks. There is a wide range of operators from community access providers to WISPs to national operators. Mobile operators usually deploy their own wireless

Fixed Wireless: Access and Transport Networks	
	backhaul but there may be an emergence of 'as a service' providers in the Wi-Fi and small cell areas.
Contributions to social and economic value	Since fixed wireless is an essential enabler for mobile networks, its social and economic contribution goes beyond its own direct revenues and access services. It supports the expansion of mobile services, especially in rural and dense urban areas where fibre is difficult to access. Some types of networks can only be deployed using fixed wireless, including some used in emergency situations, which have clear social benefits that are not related to revenues. An Ofcom study of 2006 estimated that fixed wireless contributed 10% of the total economic benefit of UK spectrum, or £4.2 billion, while an Analysys Mason study of 2012 assessed the net benefit at £2.2 billion. These related to direct revenues – when mobile backhaul is taken into account the figure is far larger (€27.8 billion in 2013 across the EU, according to Plum Consulting).
Current and recent past status	Biggest market is mobile backhaul. The mobile providers account for 85% of fixed links and 55% of backhaul links in Europe are wireless (a figure that is growing with increased densification). Other markets are WIFi backhaul; point-to-point links between enterprise locations (some super-low latency eg for financial institutions); broadband access where fibre is unavailable or expensive; redundant backup for critical wireline links; temporary or emergency networks. Rural access is important because of EU NGA mandates. According to INCA, 46 members operate NGA services, creating an 'altnet' across most of the UK with a mixture of wireline and wireless. An important step was the approval of fixed wireless access as an NGA technology by the EU, so operators are eligible for subsidies.
Sector trends	Increase in data traffic, and in user expectations of speed and QoS, puts pressure on mobile networks and backhaul. It is driving small cell networks in which wireless backhaul will be important in many areas. In fixed access, rural users want better quality services, providing opportunities for the fixed wireless 'altnet' providers, in rural coverage and also in 'deep infill' in urban areas. It is also driving a shift from proprietary or 802.11 technologies to LTE. Private networks are also moving to LTE standards eg transportation (LTE-R), TETRA (eLTE) and M2M (LTE-MTC). Support for standard devices will broaden opportunities in emerging markets like smart cities

Fixed Wireless: Access and Transport Networks	
	(eg UK Broadband's smart city, smart rail and smart campus LTE services). Emerging opportunity to offer wholesale wireless data capacity to MNOs, MSOs or vertical virtual network providers.
Spectrum usage	Below 6 GHz, common bands for fixed wireless are unlicensed 2.4 GHz and 5 GHz; lightly licensed 5.8 GHz; licensed 3.4-3.6 GHz. Fixed LTE links may be supported in mobile spectrum (2.6 GHz, 1.8 GHz or 800 MHz). The 'workhorse bands' for wireless backhaul are the microwave frequencies from 6 GHz to 55 GHz – long haul below 11 GHz (Macro backhaul and rural); medium haul in 11 GHz to 23 GHz (suburban); above 23 GHz for dense urban and small cells. The millimeter wave bands between 55 GHz and 300 GHz are of rising interest for their capacity and are licence-exempt (notably in 60 GHz) or lightly licensed. Technologies are immature as yet and licensing regimes fragmented. There are four main spectrum access approaches for fixed wireless services – individual per-link licences centrally coordinated by Ofcom; licence-exempt; self-coordinated with spectrum access on a first come first served basis; block assigned, usually at auction (eg 10 GHz, 28 GHz, 32 GHz and 40 GHz bands). Traditional per-link P2P assignment methods will often be unsuited to small cell backhaul in high frequency bands so the other methods are expected to come into greater use along with light licensing and Licensed Shared Access. There is a move to support greater spectrum sharing, to improve the usage levels in each band. Most FWS bands already share spectrum allocations with other services eg with Satellite Service Permanent Earth Stations in 4 GHz, 6 GHz, 7.5 GHz, 13 GHz & 17/18 GHz. UKB is the largest fixed wireless access provider, with its network deployed in 3.5 GHz. It also has 84 MHz in the 3.9 GHz band, plus spectrum in 28 GHz and 40 GHz for wireless backhaul and a licence for low power GSM in 1.8 GHz, which it uses for in-building voice coverage.
Expected technology & spectrum changes	FWS changes will be driven by the needs of the largest market, the MNOs. Their adoption of high capacity access network options eg MIMO, carrier aggregation, will increase demand for backhaul capacity. Small cells will drive demand for wireless backhaul which will often be cheaper and more flexible to deploy to large numbers of sites. This will also boost new wireless backhaul approaches eg a larger role for point-to-multipoint and millimeter wave.

Fixed Wireless: Access and Transport Networks	
	Another MNO architecture change, Cloud-RAN, will require high speed fronthaul links. These are currently fibre but there is work on wireless fronthaul technologies as a lower cost alternative especially where C-RAN and small cells are combined. Wireless fronthaul relies on the same kind of high end microwave links that are evolving for high capacity backhaul. Licensing schemes will diversify, especially for millimeter wave, where the schemes are currently fragmented. LSA and light licensing expected to play a bigger role. Technologies for fixed wireless access are evolving too, mainly around LTE, often in unpaired spectrum. Eg UKB is deploying TD-LTE in 3.5 GHz with peak rates of 440 Mbps. There are also emerging networks for the IoT and smart cities, such as SIgfox and LoRa. Relaxation of planning regulations is needed for small cells and Wi-Fi to succeed, according to INCA. That will help address spectrum shortages, by allowing more flexible usage. Smaller providers also need better access to dark fiber and mobile masts. An expanding use of fixed wireless is for low latency data transfer, especially in the financial services sector, with 'faster than fibre' performance over dedicated links.
Long term needs and options	The emergence of 5G technologies will shape the future FWS market, both directly for access, and by driving mobile backhaul directions. They are likely to include even more dense networks, use of millimeter wave spectrum for access, and virtualisation of the network. UKB has a roadmap to expand LTE and introduce new '5G' technologies (it holds spectrum in the 3.5, 3.6 and 3.9 GHz bands). It aims to more than double its capacity by 2020 using next generation 3GPP advances such as massive MIMO, massive carrier aggregation, 80 MHz channels and LTE in 5 GHz. High frequency bands right up to 300 GHz may come into play in 5G. A GSMA/ABI study forecasts that millimetre wave will account for almost 30% of small cell backhaul usage in Europe by 2019, up from less than 4% in 2013. Microwave will still be the biggest player, accounting for almost 36%, down from 56.7%. Other techniques to enhance the speed and capacity of fixed wireless, for backhaul, access and fronthaul, will emerge from the labs over the next few years. They include channel widths up to 112 MHz in lower frequencies and wider in millimeter wave; modulation up to 4096 QAM; systems which can adapt to different bandwidths on the fly; polarisation multiplexing; full duplex radios for self-backhauled small

Fixed Wireless: Access and Transport Networks	
	cells; asymmetrical P2P; multilayer header compression; radio link bonding. More generally, there will be increased use of SDN and SON in fixed wireless.

Amateur radio	
Scope of sector	A wide range of applications, all of which use designated frequency bands for strictly non-commercial activities. Radio amateurs are licensed based on their passing certain tests, and despite their non-commercial activities may be as experienced and well trained as professional radio users.
Contributions to social and economic value	One calculation suggests the spectrum used by UK amateurs may carry a value of around £64 million. The AR community contributes to the UK's technology skills base, providing knowledge and education (at no cost). AR activities lead to the development of radio technologies such as narrow split duplexing filters and in-depth understanding of propagation effects. Radio amateurs also operate voluntary communications services which can bring relief in emergency and disaster situations: examples include the North Sea flood in 1953 and the Lockerbie air disaster in 1988. The ITU Handbook on Emergency Communications states: "In situations where a professional and helpful attitude is maintained, served agencies point with pride to Amateur Radio volunteer efforts and accomplishments. Although the name says "Amateurs," its real reference is to the fact that they are not paid for their efforts"
Current and recent past status	There are about 70,000 UK licences, according to the RSGB (held by about 60,000 individuals, as some have multiple licences). UK usage has been increasing over the past decade, with about 8,000 new licences issued in 2011-2014. A widening variety of applications include traditional continuous wave (CW) communications digital TV, digital voice and data, and EME (earth-moon-earth) links. These are supported by an infrastructure of 265 simplex gateways; 480 duplex voice/TV repeaters to boost coverage; 100 propagation beacons and many hundreds of datalinks.
Sector trends	Recent years have seen significant convergence of radio networks and the internet, with AR acting as a trailblazer - support for TCP/IP over amateur packet radio networks preceded the public Internet. Position and weather reporting capabilities are increasingly incorporated into radios. The number of young people joining the AR community is in decline and there is a STEM-related drive to re-engage and inspire young people via

Amateur radio	
	greater focus on AR applications for modern data devices such as tablets. Technology trends include the emergence of increasingly software-defined radios, with much SDR development being contributed from the AR sector itself, such as the DttSP SDR library, the DREAM project, the GNU radio and the High Performance SDR project. AR is also working on the recovery of very weak signals, below the noise floor. Amateur satellites are also on the rise, with over 40-existing amateur satellites and plans to launch some 100 tiny microsats/cubesats. Most are in low earth orbit, but two projects will soon launch the first geosynchronous orbit (GEO) satellites for AR use. Challenges for AR include increased noise from equipment with poor EMC characteristics such as plasma TVs, LED lights, land-based wind generators, and VDSL equipment.
Spectrum usage	Frequencies in common use for amateur radio around the world reach from 136 kHz to 248 GHz. The HF bands between 3.5 and 29.7 MHz are by far the most popular. Most digital developments are targeted on the VHF/UHF frequency bands between 50 and 440 MHz. According to Ofcom's Spectrum Attribution Metrics (December 2013), an overall average of 3% of spectrum was allocated for amateurs, and 1% for amateur satellite
Expected technology & spectrum changes	The spectrum range used by AR is likely to extend both upwards and downwards – operations at 9 kHz and 275 GHz have been tested internationally. Digital systems will extend into the 71 and 147 MHz frequencies in the near future. Ofcom's Public Sector Spectrum Review (PSSR) saw amateur services losing 40 MHz in the 2.3 GHz band and 65 MHz in 3.4 GHz, with the most serious impact falling on wideband datalink and TV applications. On the plus side, Ofcom did grant access to an unused segment in the 2.3 GHz band (2 300 - 2 302 MHz).
Long term needs and options	The main issue in most areas of the spectrum is interference, especially as many AR communications use weak signals The HF and lower VHF bands have become less congested because of lower usage by broadcasters and some PMR (not by AR), while the opposite pattern is seen higher up the spectrum Primary allocations are a critical issue and the RSGB believes current AR primary allocations are insufficient. The biggest gap is the absence of any primary allocation between 400 MHz and 24 GHz, which creates restrictions that can threaten confidence, investment and growth in AR.

Amateur radio	
	The problem is greatest for satellite transponders, EME and narrowband terrestrial systems. Additional spectrum is needed to relieve digital voice congestion, enable new technology experimentation, introduce and extend digital TV, introduce new data modes and higher speed data technologies and to continue to enable the UK's lead in small satellites.

Real Wireless Ltd
PO Box 2218
Pulborough
West Sussex
RH20 4XB
United Kingdom

t +44 207 117 8514
f +44 808 280 0142
e info@realwireless.biz
www.realwireless.biz