Department for Culture Media & Sport

The UK Spectrum Strategy

Delivering the best value from spectrum for the UK

10 March 2014

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Ministerial Foreword

Spectrum underpins our modern lives. We can't see or feel it, but without it we would have no mobile phones, no TV and radio, no radar, no safety of life services…the list goes on. We know we cannot make more of it, though we can use it more efficiently.

Spectrum is hugely valuable. In economic terms it is already worth over £50bn a year to the UK economy. We are confident that we can grow that value from spectrum's direct use significantly and the indirect impact on businesses which rely on communications will multiply the effect on economic growth. In societal terms spectrum allows us to enjoy live entertainment and broadcasting, to travel safely, to communicate when on the move, and to keep our critical infrastructure working. Technical innovation is finding exciting new uses such as machines talking to machines, doctors conducting routine health checks remotely, as well as new techniques that enable us to share spectrum so we can squeeze more value from it.

We have always been keen to innovate in the way we manage spectrum and to widen its use as far as possible. Our approach has given business and the public sector confidence to invest in the services we need and value. But the years ahead present new challenges. We want to make the most of any globally agreed changes in spectrum use, such as those which will support ubiquitous mobile broadband. And we want to be a global leader in driving better value from spectrum, for example from white space devices.

Our vision is for use of spectrum to double its annual contribution to the economy 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.

To achieve this we will work with Ofcom and with spectrum users to adopt a holistic approach to managing spectrum, and in particular to managing change of use well. We will work through the international organisations to reap the benefits of global harmonisation while supporting the services in the UK which we prize highly. We will apply the same core principles to all who use spectrum in the UK, or want to use spectrum, whether they are from the public sector or private sector. Through clear incentives we will encourage the use of spectrum by those who will deliver best value. And we will continue to seek to attract those who will innovate by making spectrum available to those who will venture into new areas.

Ed Vaizey MP
Minister for Culture, Communications and Creative Industries

Introduction

1.1. Spectrum is the airwaves over which all wireless communications devices (televisions, mobile phones, tablets, radios, microphones and more) communicate.

1.2. Spectrum is also vital for a wide variety of other devices, technologies and industries that are critical to the economic and cultural success of the UK. Those uses are essential enablers for the financial services, online shopping, logistics management for manufacturing and much more. Spectrum enables radar for air traffic control and meteorological services, communications for the emergency services, defence and security communications, operation of satellite networks, telemetry and monitoring services that keep our energy networks and other critical national infrastructure operating. New applications, for example in health, have the potential to transform how we deliver and use public services.

1.3. Because spectrum is so useful, it is also valuable. In a report we published in November 2012, Analysys Mason[1] estimated that spectrum contributed £52 billion to the economy in 2011, representing an increase of 25% in real terms over 5 years. That report was commissioned to help us understand the potential value from achieving our goal of releasing 500MHz of spectrum below 5GHz from public sector use by 2020, and it deliberately made no attempt to place a value on the current public sector uses such as for national security, the emergency services, science or transport systems.

1.4. Spectrum is finite – we cannot physically make more of it though innovation allows us to increase the range of usable spectrum. We are all aware of how access to broadband is transforming our lives, and increasingly we expect that capacity to be available wherever we are. And it is not only people who want to communicate with each other – so do machines. The number of machines 'talking' to each other will soon outstrip the number of people on the planet, and while each individual communication may use only a small amount of spectrum, the cumulative effect may be significant in terms of demand for spectrum and increased economic and social benefits. These are two examples among many of the growing demand for spectrum which we must manage well.

[1] https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand

1.5. We must encourage existing users to make better use of what they have, and to release what they no longer need. It should be simple to make frequencies available for testing innovative applications. Technology is helping here by making it possible to share spectrum more intensively. Getting more out of spectrum has a cost and complexity to it that sets challenges for the regulatory framework. We need to keep that framework flexible to respond to change, but sufficiently stable to encourage innovation and investment, with an emphasis on incentivising different users to co-exist in the same space without interfering with each other.

1.6. Our vision is for use of **spectrum to double its annual contribution to the economy 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**. That is why we need UK Spectrum Strategy now, to set the framework to help us make the right choices in the years to 2025 and beyond.

1.7. The UK has led the way in Europe in developing and implementing effective ways of managing spectrum. We need this to continue as the importance of spectrum's role in underpinning growth increases. We have moved away from government having full control of who could use what airwaves for which purpose and replaced this with applying market mechanisms to spectrum management. This was new in 1998, but is now embedded, although we have more to do in making sure that incentives to use spectrum well work effectively across public and private sector users. For the future we will also encourage innovation through various sharing arrangements. For example, Dynamic Spectrum Access technology, being tested in the spectrum used by TV, can in theory be deployed across all spectrum. The potential to radically increase the value derived from spectrum use is immense.

1.8. In our ***Information Economy Strategy 2013***[2] we set out how we will support innovation and growth, including through our communications infrastructure. Spectrum is both the key raw material for infrastructure and the means of enabling business to thrive. We intend to be at the forefront of developing 5G mobile technology. We see 5G as providing 'always sufficient' bandwidth to give the consumer the perception of infinite capacity. We are taking a new approach to making spectrum available for research and development, whether for 5G or other advanced applications. Adequate and effective spectrum provision for 5G will be necessary, commensurate with expected developments, needs and balanced spectrum use.

1.9. In ***Connectivity, Content and Consumers***[3] we set out our intent to retain the UK's pole position in the G20 for the contribution by the digital economy to GDP, and our ambition for everyone to benefit from the opportunities that come with world-class

[2] https://www.gov.uk/government/publications/information-economy-strategy

[3] https://www.gov.uk/government/publications/connectivity-content-and-consumers-britains-digital-platform-for-growth

connectivity. To do this we are investing in broadband, supporting mobile telecommunications, making infrastructure deployment easier and supporting digital inclusion. We also committed to making better use of spectrum.

1.10. This Strategy builds on these commitments. We have some key parts of the Strategy in place already. Ofcom, the body responsible for managing much of the UK's spectrum, published its Spectrum Management Strategy[4] for comment on 2 October 2013. We also have the government's specific plans[5] for releasing spectrum from public sector use and we are publishing a progress report on those plans to accompany this Strategy.

1.11. This Strategy takes a holistic approach that will over time allow the distinctions between public sector and private sector spectrum use to dissolve, with the same core principles applied to access to spectrum and continuing use whatever the frequencies concerned and regardless of whether the user is from the public sector or the private sector. We clarify the roles of Government and Ofcom and commit to making sure that each has the resources needed to deliver the objectives together.

1.12. Our Strategy also sets the principles for our approach internationally. Radiowaves do not respect national borders. International coordination is an essential element of making it technically and economically possible to use spectrum in the UK. Hence it is important that we continue to engage actively in the International Telecommunications Union, in the European Conference of Postal and Telecommunications Administrations, and in the EU spectrum bodies, seeking always to promote coordination that leads to a regulatory framework that provides confidence for investors, supports innovation, and delivers best value.

1.13. We are setting out here how Government and Ofcom will work together to deliver the best outcomes for the UK from the use of spectrum. It will show that by working closely with spectrum users, from all sectors, and with a robust domestic and international governance model that hears evidence from all sides, authoritative and well-judged decisions on spectrum policy can ensure the economic and cultural success of the country for many years to come. We will enable change of spectrum use to happen over time to the benefit of the UK, with a gradual move away from exclusive use to shared use of frequencies.

1.14. Spectrum is the core asset for the wireless economy. We will continue to be innovative in how we manage spectrum so that in turn innovation in technology and business can flourish. From 5G mobile, to Machine-to-Machine communications for smart metering, to dynamic spectrum access techniques to make the most of

[4] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/

[5] https://www.gov.uk/government/publications/enabling-uk-growth-releasing-public-sector-spectrum-march-2011

spectrum used by TV or the MOD, we will strive to grow the value delivered from spectrum. Working together, our aim is to elicit the best economic and social value for the UK from spectrum.

1.15. Throughout the Strategy, we will highlight various actions which will form the basis of the delivery of our priorities and goals. A consolidated list of these actions is in Appendix 1.

The value of spectrum to the UK

2.1. Spectrum is a major national asset, serving as a critical input to a wide range of services including mobile communications, television and radio broadcasting services, emergency services communications, air travel radar and many more. Through these services, spectrum use delivers substantial benefits to citizens and consumers. It is a finite resource but demand to use it is growing – both in terms of new kinds of application and in terms of the amount needed to support more widespread and richer use of current uses such as mobile broadband. Spectrum is therefore an incredibly valuable raw material for technological development.

What is spectrum?

2.2. When appropriate electrical signals are applied to an antenna they result in electro-magnetic waves which radiate outwards. It is this property that is at the heart of wireless communications. These waves can be received some distance away from the transmitter using appropriate antennas and receiving equipment. They can be transmitted at different frequencies.

2.3. A particularly important property of these electro-magnetic signals is that signals transmitted on different frequencies (suitably far enough apart) do not interfere with each other, even if they are transmitted in the same place. Using a receiver that is selective enough, it is possible to receive the desired signal and remove the unwanted signal.

2.4. The set of usable frequencies is often termed the “radio spectrum”. As technology progresses, the boundaries of useful frequencies are continually extended.

2.5. The UK Frequency Allocation Table[6] (UK FAT) sets out all the allocations of UK spectrum from meteorological aids operating at 8.3 kHz through to earth-to-space satellite links operating at 275GHz. Within this range are applications of major commercial value such as mobile telecommunications, television and wireless broadband. There are also applications of key social value such as defence and security communications, and support for the emergency services. Many of the commercial benefits of spectrum use can only be achieved and secured in the context of the social contribution of spectrum deployment.

[6] http://stakeholders.ofcom.org.uk/spectrum/information/uk-fat/

Why is spectrum important?

2.6. Radiocommunications underlie many aspects of our lives and are critical to areas such as air travel, emergency services, mobile broadband, sound and television broadcasting, defence, the management of utilities and the monitoring of our environment. Spectrum is, however, finite in that use of a specific frequency for one purpose or by one user at a given location will generally exclude or limit its use by others. As innovation enables, the boundaries of usable spectrum expand, but we must ensure that the spectrum is well managed if we are to make most effective use of it.

2.7. Different frequencies have different physical characteristics that make them more suitable for one type of application over another. For example, lower frequencies tend to travel further, be less susceptible to rain attenuation and penetrate buildings better compared to higher frequencies. Higher frequencies may need line of sight (for example the satellite TV antenna fixed to a home needs to be visible to the satellite which is broadcasting services) but provide larger bandwidths and therefore support high capacity uses.

2.8. Figure 1 below illustrates how the radio spectrum is used and shows the 'sweet spot' that is often considered the most attractive frequency range for commercial exploitation, because it can be used for mobile applications and has sufficient capacity to carry broadband and video broadcasting.

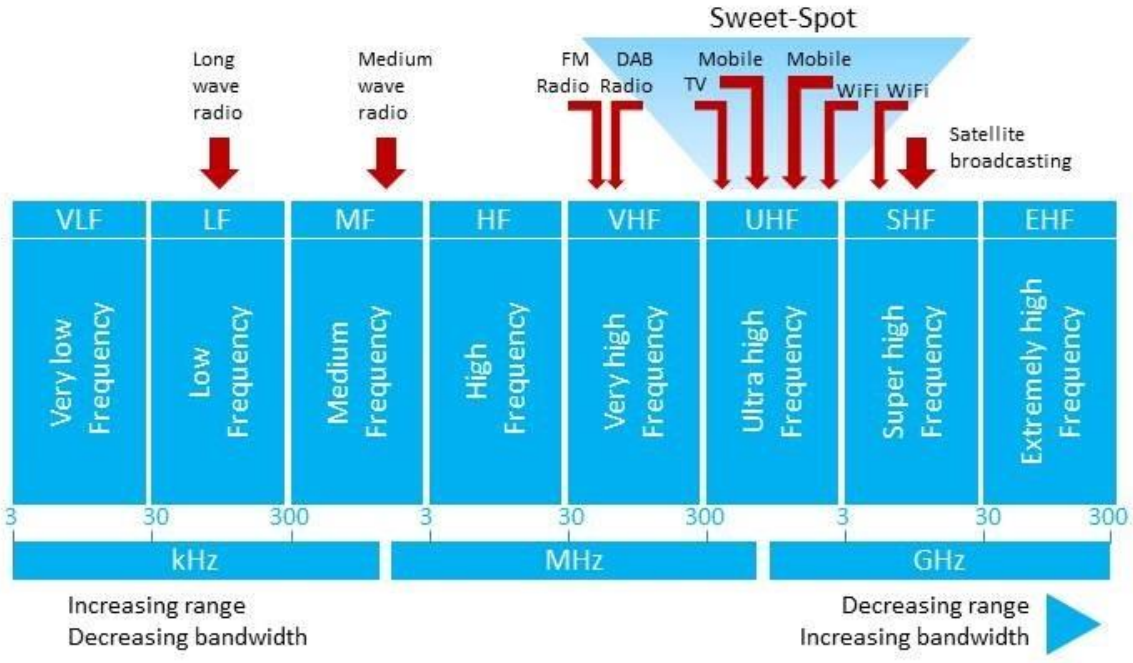


Figure 1: Radio spectrum frequencies and corresponding usage

2.9. There are a number of different ways that spectrum delivers value for the UK:

- There are *direct* users of spectrum who generate economic value – for example commercial communications services;
- There are *indirect* users of spectrum who generate economic value in part through relying on communications which use spectrum e.g. businesses which use mobile broadband and/or Wi-Fi, or use business radio;
- There are users of spectrum who primarily deliver social value e.g. the emergency services, defence, or transport control systems.

2.10. These categories are not mutually exclusive. The use of spectrum by broadcasters contributes over £10 billion each year[7] to the economy but also has a recognised public service element. The use of spectrum by radar systems at airports primarily enables airports and planes to operate efficiently. It also generates social value in terms of safe air travel for passengers and local residents. This in turn contributes to the net economic and social benefits resulting from tourism and business travel. Through innovative applications in telemedicine, remote monitoring, and ubiquitous broadband we can expect to benefit from the transformation in digital delivery of public services using spectrum.

2.11. **Our aim is to elicit the best economic and social value for the UK from spectrum**. That poses questions about how to assess 'best value' and how to deliver it. This chapter focuses on how to assess value. The next chapter focuses on how to deliver that value.

2.12. The potential use value of spectrum depends upon how well it is managed because electromagnetic spectrum is not a normal economic good; it is a commons. In the absence of coherent management, its use by one user interferes with its use by all others and means that no-one benefits from it. This means that the value of spectrum depends crucially on how well it is managed so that as many potential users as possible can benefit.

2.13. The analysis of the economic and social value of spectrum has largely been confined to computation of its economic or financial worth to private, individual decision-takers. However, spectrum also has a value to the state, communities and social and economic groups which goes beyond, and is not captured by, its value to persons considered individually. Moreover, many uses of spectrum are hidden and only become obvious when they cease to function as intended. For example, the use of spectrum by the police, courts, prisons and probation service, including in the transfer of prisoners, helps ensure that property rights can be enforced and enjoyed and social relationships are not subject to arbitrary or unexpected disruption. Quantifying the social value of different uses of spectrum is challenging but necessary. As part of this spectrum strategy, we intend to move towards a comprehensive system for valuing spectrum that keeps economic value as its

[7] Analysys Mason

bedrock, but extends this to take a range of social costs and benefits into proper account.

Valuation Procedures

2.14. Spectrum is not usually needed for its own sake but as an input into a variety of applications. When computing the value of spectrum in a particular use it is important *not* to count the total social and economic value of the use to which it contributes as the value of spectrum. Rather, the value of spectrum is more precisely indicated by the difference between the current use value (net of costs) of that application and the use value (net of costs) that would obtain if spectrum were not available. In effect this is the value foregone by depriving users of spectrum. It is, therefore, called net deprival value.

2.15. An appropriate valuation system will inform decisions about the overall allocation of spectrum to a variety of social uses. These include the provision of emergency services, defence and national security, and air traffic control. It will assist in determining the timing and extent of changes in the use of spectrum. However, in the present inexact state of valuation science of social benefits it is unlikely to be the sole determinant of these matters.

2.16. The Government must make decisions about the use of a variety of socially and culturally important assets quite apart from spectrum. It would be helpful, therefore, to develop valuation procedures which are as consistent, transparent and complete as possible. Such procedures will provide a coherent basis for strategic decisions about all Government assets including spectrum. Thus, the aim in spectrum valuation is to develop valuation procedures which are commensurable with those used elsewhere in Government.

2.17. We believe that the spectrum valuation framework should have four components. Simplified versions of each element of the total framework could be introduced separately and subsequently bolted together to form a more complete system. It is also possible that two or more elements might be combined in a single procedure. For clarity's sake we consider them separately.

2.18. The main behaviours and constraints surrounding the use of spectrum must be identified. It is necessary to ensure that all major issues and impacts are considered so that a complete and consistent account of likely impacts can be compiled.

2.19. This account may take a variety of forms including a model or a list of key variables. Its minimum requirements are that it:

- Is dynamic, i.e. takes account of time;
- Considers social factors and technology as well economics and finance; and
- Makes legal and technical constraints explicit.

2.20. A general account of alternatives of this type is important to ensure that socially and economically valuable future uses of spectrum are not ruled out by allocations made now. A variety of measures which could potentially provide the required flexibility can be considered. They may include promotion of an active secondary market in spectrum, the Government holding spectrum in a contestable pool, or the Government acting as a broker for spectrum. It is likely that a number of such tools will be developed under the UK Spectrum Strategy.

2.21. To be usable, we need to establish consistent valuation criteria that are as general as possible. Such criteria are based upon ideas about better or worse uses of spectrum. Spectrum value may be defined and measured in a number of ways. For example, in terms of final use (e.g. saving life) or cultural potentialities (e.g. social resilience or connectivity) or moral or cultural imperatives (e.g. the state has precedence over its use). In some cases, measures of these kinds of values already exist. It may be possible to provide a numerical value. However, elsewhere, using existing proxies or newly created metrics, ways must be identified and/or developed to show the degree to which a given impact satisfies a given valuation criterion. Pending the development of more precise measures it may be useful in considering social or more intrinsic and hard to measure impacts to employ impact upon well-being measures (e.g. life satisfaction) as the valuation criterion.

2.22. In principle, any method of valuation which satisfies these valuation principles should be valid. The key objective is to ensure that the social and economic value of spectrum is computed in as consistent, transparent and complete manner as possible.

2.23. Planning the use of spectrum involves ranking the relative public values of various uses. This implies developing a method of making judgements about relative worth that is as consistent and complete as possible. We will need to find ways to weigh social, economic, financial, technological and political factors against each other. It is likely that, in practice, this will be developed over time as it becomes possible to make social and economic impacts commensurate with each other.

2.24. A number of options might be applied including Red Amber Green ratings, net deprival value, or rank order as well as monetisation. Each can be applied, as appropriate, to the circumstances applicable to the impact under consideration. In doing so, however, it is important to ensure that easy-to-understand procedures like monetisation are not permitted to dominate other methods which may be less coherent but which, nonetheless, articulate important public values. Use of well-being valuation techniques may avoid many of the pitfalls associated with other methods.

2.25. The valuation system must facilitate judgements about the public value of alternative uses of spectrum taken individually as well as alternative strategies for spectrum use. This involves bringing the judgements about public values into as complete and consistent a form as possible. It implies comparison of different rankings made in different ways. Such comparisons are possible through agreed

protocols which translate different types of ranking into a consistent scoring system. It is necessary to develop a protocol to compare the public value of spectrum use across many types of impact and across time periods. Similar protocols have been developed to guide allocation of resources to different treatment procedures.

2.26. There may be a number of valuation procedures which meet the Government's valuation principles. For this reason the Government will undertake research into methods of social and economic valuation which satisfy the conditions of consistency, transparency and completeness.

2.27. As a first step, we propose to investigate the use of well-being valuation (WV) techniques to provide an overall assessment of the relative worth of alternative uses of spectrum in delivering public policy objectives. These techniques are particularly well-adapted to situations in which the impacts of a particular alternative are difficult to identify. WV techniques are based on an estimate of the impacts of different spectrum uses, income and a vector of other factors on life satisfaction. The trade-off between a particular spectrum use and income for a given increment to life satisfaction can then be calculated; the higher the relative impact of a particular spectrum use the greater its value.

ACTION: We will develop a consistent methodology for assessing the full value of spectrum to the UK. To help us in this work we will invite a panel of experts to advise on options, and we will publish our conclusions by July 2015.

2.28. Analysys Mason's report for DCMS and BIS[8] considered the value of spectrum use to the UK economy, key changes in spectrum use and requirements that can be expected by 2020 and the implications for policy-making, including the UK Government's plan to release 500MHz of spectrum from public sector use for commercial use by 2020. According to the study, the economic value of spectrum use was £52 billion in 2011, an increase of 25% in real terms since 2006, the last time a similar study was undertaken. The study showed mobile services accounting for nearly 60% of this value, while broadcasting accounted for a further 20%. Other sectors considered included the use of Wi-Fi as a substitute for mobile broadband, microwave links, satellite links and private mobile radio. Another key finding was that public mobile communications supports a supply chain of infrastructure, equipment, applications and content providers generating annual revenues of around £20 billion and supporting 75,000 jobs, while broadcasting services supported a supply chain worth around £16 billion a year and supporting 40,000 jobs. This report provides one example of how we can evaluate the impact of direct spectrum use.

2.29. In parts of the transport sector, such as aviation and maritime, major contributions are made to the UK economy not only through the direct value of these

[8] ibid

networks but also in the support they give to the economic viability of many other service industries. Maritime for example contributes £14 billion and aviation £50 billion each year to the economy and rely extensively on radio and radar systems to ensure safety.

2.30. Access to spectrum is key for the success of the programme for smart electricity and gas meters to be rolled out across the country. Licence exempt spectrum supports the Home Area Network providing for secure wireless communications of energy data between smart meters, an In-Home Display and other consumer devices within the premise. It also enables the Wide Area Network, the means by which data is transmitted to energy suppliers, network operators and other parties contracted to the central Data and Communications Company. By the end of 2020 every home in Great Britain should have a smart energy meter and be using it to manage energy consumption, unlocking over £6 billion in net benefits to the economy. A similar scheme in Northern Ireland will add to these benefits.

2.31. The Defence Industry is a leading high technology sector worth an estimated £35bn to the UK economy and employing over 300,000 people. The manufacture and sale of a wide range of spectrum dependent equipment, from ships and aircraft to personal radio communications, make up a significant proportion of the industry's business.

2.32. The UK's thriving space sector contributed £4.1billion in Gross Value Added in 2011, on a par with the contribution from the UK film and television industry. In 2011 there were 234 companies in the UK space industry, ranging in size from sole traders to large multinational companies, and employing 28,900[9]. The average growth rate 2006-2012 and through the recession has been a robust 7.5% per annum. At the current rate of growth we expect the space industry to have doubled in size within the next 10 years. The UK Space Agency has recently published a strategy aiming to grow the UK space sector to £40bn p.a. by 2030, to generate 100,000 new UK jobs and to capture 10% of the world market. While broadcasting and telecommunications currently dominate the space economy, the important public-good areas of science, especially Earth Observation, should not by under-estimated. For example the recent accurate prediction by the Met Office of the St Jude's day storm (28th October 2013) five days in advance, which allowed the impact to be minimised, was largely due to the exploitation by advanced supercomputer modelling techniques of observations delivered from reliable satellite access to key radio frequency bands. Increased demand for spectrum is expected across all space sectors, from telecommunications to remote sensing.

[9] The Size and Health of the UK Space Industry – October 2012, Oxford Economics http://www.bis.gov.uk/assets/ukspaceagency/docs/industry/size-and-health-report-oct-2012.pdf

2.33. Another example comes from telehealth. A UK company is developing a method of detecting blood sugar levels for monitoring diabetes in humans by using a handheld device (between thumb and forefinger). This makes use of spectrum in the 60GHz band to take glucose readings which are instantly displayed on the device or can be transmitted via Bluetooth to a mobile app, where the patient can manage data and receive alerts. The UK spends £10bn a year on treating diabetes, so a simple monitoring system which reduces the need for medical intervention has the potential to deliver significant economic as well as social benefits.

2.34. The telehealth example shows the economic impact, but clearly there is also a different social value from meeting health needs – and an additional value, potentially both economic and social, from being able to meet the medical needs of someone in their own home instead of in a hospital. Similarly, in the space and publicly-funded science areas, the public good values of space derived data, for example more accurate weather forecasts, predicting flooding, monitoring the drivers for climate change, and space exploration are all difficult to quantify in purely economic terms. If we are to be able to make best use of spectrum for the UK, we need some consistent way of evaluating social value. We should be able to use a common methodology for evaluating potentially competing uses for a given spectrum band when taking future decisions about public sector spectrum releases.

ACTION: We will apply the same principles for valuing spectrum use across all sectors.

Getting the best value from spectrum

3.1. It is clear that with demand for mobile broadband and other commercial services set to rise potentially up to 300 times current levels in the next fifteen years, the need to use spectrum as efficiently as possible has never been greater. A 2012 report by Real Wireless for Ofcom[10] predicts, in the medium-demand case with 'steady growth', an 80-times increase in demand for mobile data by 2030, equivalent to about 2,000 petabytes of data per month in the UK alone. In 2013 Cisco forecast[11] that by 2017 there will be more devices using machine-to-machine communications than there are people in the world, accounting for 563 petabytes of data per month. We need to plan to meet this demand and also to make sure that the benefits are enjoyed as widely as possible. For example, sustaining mobile broadband growth, including the delivery of high-capacity services to rural areas, will enable businesses to grow and also enable our rural communities to be fully included in that growth.

3.2. Technology is changing the way in which spectrum is used. New uses, such as machine to machine (M2M) communications, will become increasingly important and will demand spectrum. We can expect to see a demand for more very short range spectrum, for devices in close proximity to communicate with each other. The communications path will have to be more robust than at present if we are to have safety and critical features dependent on the radio channel. This translates into such aspects as low interference, new spectrum, better use of existing spectrum etc. Existing users are also looking to use spectrum in new ways. For example, mobile telephony network operators now make increasing use of Wi-Fi to reduce the demand for spectrum on scarce frequency bands, and the industry is investigating ways that mobile users can share frequencies with other users. Our strategy for allocating and managing spectrum needs to be able to respond quickly to these changes. At the same time, we must take account of the potential disruption to existing spectrum users, and strike the right balance to encourage investment in current as well as future applications.

Core principles for spectrum management

[10] http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

[11] http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

3.3. Today management of the radio spectrum is split between Ofcom and Government. This is a legacy from the days before Ofcom was formed in 2003, when all spectrum was managed by Government, with the Ministry of Defence responsible for military use and the Radiocommunications Agency responsible for civil use. The MOD continues to manage the spectrum which is designated primarily for military use. The Communications Act 2003 passed most of the responsibilities of the RA to Ofcom except for spectrum used by Crown bodies for which no licence had ever been required as a result of Crown immunity. These bodies include the Department for Transport for use for radar at civil airports, the Department for Business Innovation and Skills for meteorology, satellite, space and other science applications, and the Home Office for some emergency services. The Scottish Government is responsible for managing some spectrum for emergency services in Scotland.

3.4. In order to make the most of spectrum for the UK we need to take a more holistic approach to its management. The importance of Government and Ofcom working together to manage change, taking account of the international framework, has never been greater.

3.5. Deriving best value from the spectrum will only be possible if Government and Ofcom adopt the same core principles across all frequencies. These should be based on market mechanisms, but taking due account of social value where appropriate. We set out in the previous chapter how we will develop a methodology for assessing the full value of spectrum to the UK. Ofcom's decisions already reflect their duty to take account of the interests of citizens and consumers and so recognise social and economic value, and they will continue to do so.

3.6. Our principles for allocating spectrum bands to recognised categories of use, and then for assigning frequencies to specific users, are set out below:

- International allocation of use: we will support changes to the allocations at an international level that will deliver best value for the UK and are consistent with the Digital Single Market in Europe;
- Change of use within the UK: we will manage change of use within the UK, where it is required to meet international commitments, or where it is deemed to be in the best interests of the UK, by taking account of the economic and social impact on those affected and apportioning the costs of the change fairly;
- Assignment of spectrum to new users: we will use the process to assign spectrum to new users which is likely to deliver the best value to the UK, whether through auctions, comparative selection processes, 'first come, first served', or permitting access to spectrum by Licence Exempt devices;
- Continuing use of spectrum: all spectrum users will face incentives to use spectrum efficiently. For spectrum not acquired through an auction, users should pay a market-based fee except where this fee would be lower than the cost of managing the spectrum (whether by Ofcom or a Crown body). Users should be free to innovate and

make changes to how they use their spectrum, subject to any licence conditions and not causing harmful interference to other legitimate users;

- Change of assignment to users: market mechanisms should incentivise the transfer of rights to use spectrum between users, whether by outright sale of some or all of the spectrum, or by sharing. Sharing may take the form of agreement to leasing on a time or location basis to a designated second user, or may be through supporting dynamic spectrum access.

3.7. We recognise that getting best value from spectrum in the UK means working well through international spectrum forums. Global harmonisation of frequency bands and standards is a major factor in economic growth, and also in enabling the aviation industry, for example, to operate safely. The quality of the evidence used by the UK – and particularly Ofcom's public consultation process - is widely respected internationally. We will continue to make the case for changes to be made that we see as in the best interests of the UK, and equally for the maintenance of current spectrum allocations where change would not deliver net benefits to the UK. We say more on how we will do this in the next chapter. The rest of this Chapter focuses on how we will deliver best value from spectrum within the UK.

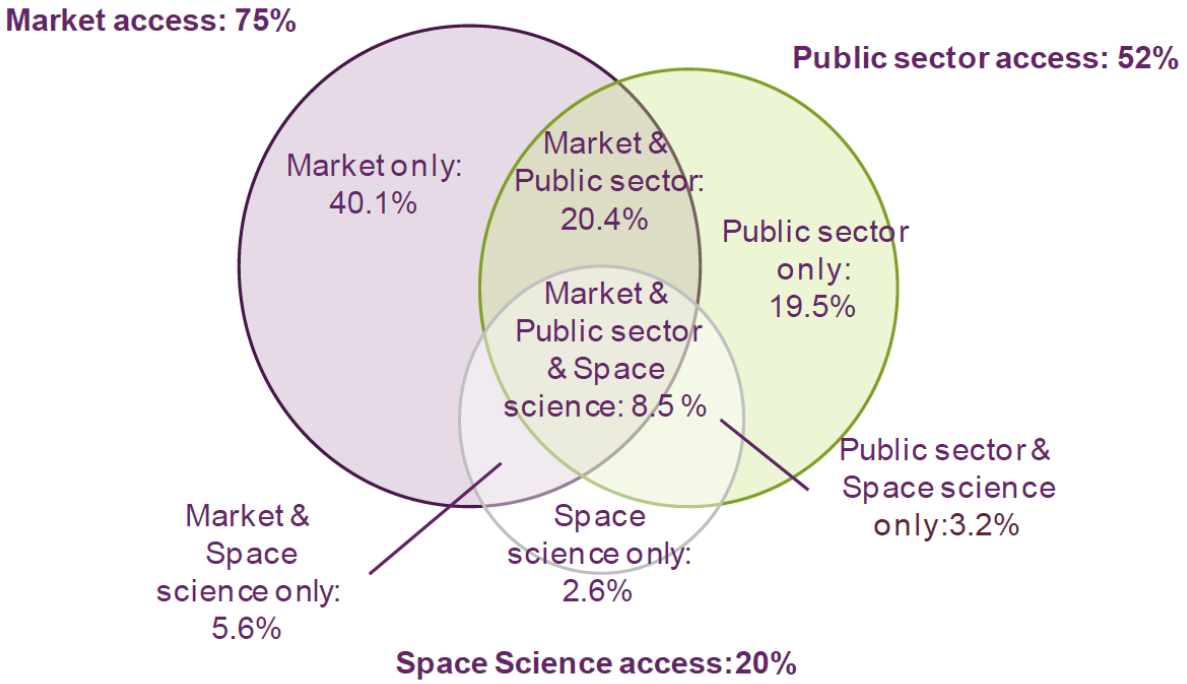
Applying the principles: Ofcom's Spectrum Management Strategy

3.8. Ofcom published on 2 October 2013 a consultation document[12] on its proposed Spectrum Management Strategy. To provide context this document included an analysis of how access to spectrum is legally permitted, which it updated and refined in a companion document published in December 2013.

3.9. At an aggregate level Ofcom defined access to spectrum as relating to one of three main categories: Market access (authorised by Ofcom and available to the market); Public sector (accessed using the immunity the Crown has from requiring a licence) or Space & Science (accessed without explicit need for a licence, or using Crown immunity). As shown in Figure 2 Market has access to 75%, Public sector access to 52% and Space & Science has access to 20%.

12 Ofcom (December 2013): http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/Spectrum_attribution_metrics.pdf

Figure 2: Proportion of total weighted spectrum accessed by Market uses, Public sector uses and Space & Science uses[13,14]



3.10. Figure 2 (which is not to scale) shows that almost 40% (37.7%) of the spectrum is shared between these three high level categories. Further analysis of the data (which is not shown in Figure 2) indicates that, of the 52% of spectrum bands to which public sector users have access, 43% (of this 52%) is managed by Crown bodies themselves[15] and Crown bodies permit access by Market uses to roughly half of this 43% (21% of the 43%).

3.11. In its consultation document Ofcom presented its initial findings of an analysis of the future developments in all of the major sectoral uses of spectrum. This analysis identified future trends in demand or supply of spectrum.

3.12. Ofcom scored future changes according to their:

- Significance, i.e. the extent to which future changes in spectrum demand and supply could cause considerable impacts on consumers and citizens, as well as the extent to which there may be a role for regulation in addressing such future potential impacts; and
- Urgency, i.e. the extent to which action (by spectrum users, industry or Ofcom) is urgently required to respond to these future changes, also by

13 Please note the Venn Diagram provided is illustrative and is not to scale

14 Spectrum bands were analysed between 87.5 MHz and 86 GHz as these are considered to be the most important and usable frequencies

15 The remaining access to spectrum enjoyed by Public sector is to spectrum managed by Ofcom and for which there are specific arrangements made for Public sector access

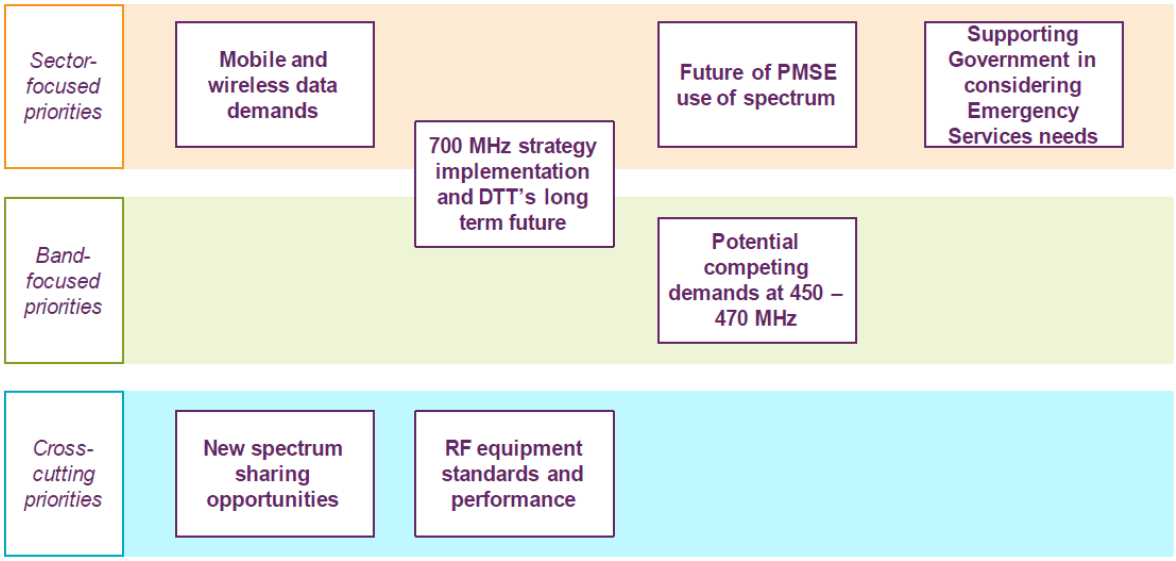
considering dependencies with other developments (e.g. in international institutions or in other sectors competing for the same spectrum resources).

3.13. The initial findings of this analysis are provided below:

Spectrum uses	Significance of potential changes	Urgency
Mobile and wireless data	High	High
TV Broadcasting – DTT	Medium	Medium
Licence Exempt and SRDs	Medium	Medium
PMSE	High	High
Emergency Services	Medium	High
Business Radio	Medium	Medium
Utilities	Medium	Low
Space & Science	Low	Low
Fixed Wireless Service – Fixed Links	Low	Low
Radio Broadcasting	Low	Low
Aeronautical and Maritime	Low	Low

3.14. Ofcom then assessed the extent to which the anticipated changes in supply and demand might require regulatory attention and this suggested seven potential priorities for Ofcom over the next 10 years. These are illustrated in Figure 3 below, according to whether they relate to challenges emerging in particular sectoral uses of spectrum (sector-focused priorities); specific bands under pressure from competing sectoral demands (band-focused priorities); or issues that could have particular relevance to a variety of sectoral uses and spectrum bands (cross-cutting priorities).

Figure 3: Ofcom assessment of priority areas in spectrum management[16]



3.15. We have not yet undertaken a comparable analysis of spectrum managed by the public sector. We intend to do so in the next 12 to 18 months. A number of examples of public sector use and the challenges they may face are at Appendix 2.

Applying the principles together

3.16. Government and Ofcom have worked together very successfully in the past on spectrum initiatives including digital TV switchover, and the clearance of the 800MHz and 2.6GHz bands to enable the combined auction for 4G mobile broadband services.

3.17. Looking forward it is clear that close working will continue to be important, particularly as the release of spectrum from public sector use and increased sharing become a larger part of the picture. In particular we will need to work closely when:

- consideration of any major change to a band will have a significant impact on Crown users as well as users authorised by Ofcom. E.g. any change to the 450-470MHz band (UHF band II) where both licensed users and Crown users have a significant interest in the band. A mechanism to undertake joined-up analysis and therefore make joint and informed decisions on the future of the band is needed;
- there are opportunities to leverage the experience of dynamic shared accessed in bands managed by Ofcom (e.g. White space devices in UHF) across spectrum in public sector use;
- public sector users consider market solutions to their future requirements, for example in the programme to look at how best to deliver the communications needs of the emergency services;

[16] Ofcom (2013): http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/summary/spectrum_management_strategy.pdf

- spectrum made available under the Public Sector Spectrum Release (PSSR) programme forms a significant part of the solution to challenges in the commercial exploitation of spectrum e.g. for “off-the-shelf” innovation licences, and as part of Ofcom’s strategy for mobile data; and
- funding is needed, for example, for clearance of, or mitigation action for, existing users to enable a change of use of spectrum and therefore Government needs to decide whether it is appropriate to fund such a change of use or not.

Spectrum Pricing

3.18. The Wireless Telegraphy Act 1998 made it lawful for the first time to charge spectrum users a fee that was designed to be an aid to managing spectrum well, rather than simply recovering the cost to the Government (or its agent) of licensing spectrum use. In 2002 Professor Martin Cave reported to the Government on the application of administered spectrum pricing (which had already by then been introduced for mobile network operators) to all other spectrum users operating in the market. The Government invited Professor Cave to report further, in 2005, on the application to the public sector.

3.19. Ofcom has extended the application of Administered Incentive Pricing (AIP) to almost all sectors for which it is appropriate and undertakes fee level reviews when there a reasonable likelihood that the fees charged are significantly out of line with the opportunity cost of its use. In 2013 Ofcom published consultations on introducing AIP for broadcasting, and on revising the rates of cost based fees for those sectors for which AIP is currently not appropriate. Ofcom also published a consultation on revising the existing charges for mobile network operators[17].

3.20. The Government committed to the same principle of setting fees based on its opportunity cost for its own spectrum use in 2006, but full implementation has been challenging. Reallocation of spectrum from public to private use raises important policy questions around the value of respective uses and how spectrum should be allocated for different purposes. The Cave report to Government in 2005 recommended that policy decisions around the value of spectrum in public sector use should primarily be the responsibility of user Departments, but that Departments should follow the principle of ‘user pays’. Decisions around assignments would not be taken centrally, but Departments should bear the market cost of spectrum to drive efficient usage. This remains the Government’s policy.

3.21. Reallocation of spectrum from public to private use raises important policy questions around the value of respective uses and how spectrum should be allocated

[17] the Government Direction requiring Ofcom to undertake this revision can be found at http://www.legislation.gov.uk/ukdsi/2010/9780111500767/article/6

for different purposes. The Cave report to Government in 2005 recommended that policy decisions around the value of spectrum in public sector use should primarily be the responsibility of user Departments, but that Departments should follow the principle of 'user pays'. Decisions around assignments would not be taken centrally, but Departments should bear the market cost of spectrum to drive efficient usage. This remains the Government's policy.

3.22. Market-based pricing based on the opportunity cost of spectrum (AIP) was introduced in principle for all public sector users in 2010, but in practice the agreed Spending Review settlements for Departments did not properly represent the spectrum for which they were accountable. For Spending Review 2013 Ofcom advised Government on the opportunity cost of frequencies which are under public sector management, and Government set an appropriate figure to be included in Departmental budgets to reflect the assignment between Departments and the bodies for which they are responsible. These sums apply for Financial Year 2015/16 and will be adjusted to reflect spectrum usage and the value of that spectrum in future years.

3.23. Market based pricing alone may not be sufficient to free up spectrum for other uses. As the current technical and remediation works undertaken by the MOD to allow for the release of 2.3-2.4GHz and 3.4-3.6GHz bands have highlighted, spectrum clearance is a complex and often costly process taking time to implement successfully. To some extent these costs can be met from receipts from sale: however, there needs to be a clear policy in place for funding the upfront costs of spectrum release and treatment of capital receipts, communicated to Departments, to support investment decisions.

3.24. We recognise that the peculiarities of Public Expenditure make it harder for the public sector than the private sector to respond to market mechanisms. It is not clear that we yet have the right arrangements in place so that Departments can pay the market rate for the spectrum they continue to need, release spectrum which they no longer use or do not value as highly as other users, and acquire new spectrum to meet their requirements.

ACTION: In order to make sure that the incentives to make best use of spectrum fall on those who can best respond to them, we will set out clearly by March 2015 the assumptions and mechanisms by which Government Departments will pay for the spectrum which they need, release the spectrum which they do not need, and be able to acquire new spectrum for future needs.

Promoting transparency through spectrum databases

3.25. Around 52% of spectrum is managed or jointly managed by the public sector. There are thousands of assignments across frequencies, time periods and regions. Efficient management of this spectrum is a major undertaking which relies on accurate up-to-date data on assignments, and suitably qualified staff.

3.26. As part of the work to establish departmental spectrum charges for 2015/16, Ofcom carried out an analysis based on available data of public sector uses, following the UK FAT allocations. This exercise revealed that there is incomplete data on actual usage of frequencies within the bands for which Departments are responsible. This may hide spectrum that could otherwise be released. Similarly it may fail to expose co-existence complexities that make apparently unused spectrum problematic to release.

3.27. The system of spectrum charges will help address this but an accurate database of public sector usage is also urgently required. Establishing a common spectrum database that is dynamic would also enable Ofcom to more effectively support departments, particularly where resources and internal expertise is limited.

3.28. The MOD, who have the largest spectrum holdings in the public sector, have developed a spectrum database as part of a major project to rationalise their spectrum usage. This database is designed to identify the users of spectrum in the bands managed by the Department, so that MOD can manage its spectrum more efficiently and are able to identify opportunities were spectrum could be shared or released.

3.29. The MOD is exploring how it can make its database available to other public sector spectrum users so that they will be better able to manage the spectrum for which they are responsible, as well as look for potential opportunities to share with MOD. Some sectors, such as aviation, already have comprehensive data on their spectrum use to meet safety and international coordination requirements. We will work with independent regulators such as the CAA to determine how we can best include the appropriate data sets in the overall public sector database. The third stage will be to enable this database of public sector use to be integrated with – or at least coordinated with – the geo-location databases which Ofcom maintains itself or will in future authorise to support White Space technologies and dynamic spectrum access.

ACTION: We will develop a single source of information on spectrum managed by the public sector which clearly identifies what frequencies are in use at what geographic locations, and hence what frequencies are available for use. This will enable the public sector to manage its spectrum more efficiently, and provide a database to underpin the determination of the charges which each user should pay for their use of spectrum.

3.30. This will be a major undertaking over a number of years. However the value which should be liberated we fully expect to justify the management and cooperation across many public bodies that will be required.

ACTION: we will ensure that this public sector spectrum database can interface with geo-location databases established by or authorised by Ofcom. This will enable in the future any potential user of spectrum to interrogate an up-to-date database of spectrum availability, and to identify who is responsible for agreeing terms for use of such spectrum.

Release of spectrum to market

3.31. One of the core principles of efficient spectrum management is for current users to release spectrum that they no longer require so that it can be reassigned by the market. This applies to public sector use as much as to private sector use. The objective is for spectrum to be in the hands of those who will generate the greatest benefits to the UK from its use.

3.32. As part of SR 2010 the Government announced a target of 500MHz of public sector spectrum below 5GHz to be released by 2020. This project, managed by the Shareholder Executive in BIS, is making good progress with 190MHz of spectrum currently held by the MOD due to be released in 2015. In the transport sector DfT, in conjunction with CAA, are managing a major programme to see determine how aviation can contribute to this Government target. A more detailed update is being published separately.

3.33. The project has raised a number of important issues including matching the spectrum released to the most pressing demands and co-ordinating releases with other policy objectives. Particular policy decisions include which bands should be prioritised for release (considering what is potentially available and what is the market demand) and the timing of releases, so that they are co-ordinated with releases of commercial spectrum by Ofcom. Ideally the supply of spectrum to the market will match demand – with no gluts or shortages.

3.34. Those making investment decisions need reliable information about what is likely to be available at what time. They do not want to face multiple simultaneous calls on their resources to acquire spectrum, nor do they want to buy sub-optimal frequencies because they were unaware of the likelihood that more suitable frequencies would be coming available shortly.

3.35. The public sector also has an important role to play in supporting Ofcom and DCMS in international discussions on spectrum allocations at regional and/or global level to help manage this long-term market in spectrum.

3.36. Decisions at the international level are critical in ensuring spectrum across public and private sector is allocated in a manner that delivers best long term value for the UK and the UK should show leadership in discussions that offer the greatest potential to deliver significant benefits to the UK.

ACTION: Public sector spectrum releases will be planned in line with releases of commercial spectrum by Ofcom and taking into account international allocation decisions.

3.37. The 500MHz project has also considered how public sector spectrum should best be taken to market. Many Departments do not have the resources or expertise to

conduct spectrum sales. The process could become complicated or delayed if Departments undertake this work themselves.

3.38. In the case of the forthcoming MOD sales (40 MHz located in the 2.3 GHz band and another 150 MHz above 3.4 GHz) Ofcom will manage this process. Having already completed a number of successful spectrum releases, including the recent 4G auction, Ofcom has significant experience and expertise in this area and is well positioned to manage the MOD sales as well as other future public sector spectrum releases.

ACTION: Public sector sales of clear spectrum will be handled by Ofcom.

Spectrum sharing

3.39. We need to share spectrum more. As clear spectrum is becoming harder to find, demand for key spectrum bands keeps growing and sole use of spectrum represents increasingly inefficient use. Spectrum sharing will be crucial. Technical and regulatory innovations to enable such sharing must be prioritised.

3.40. Currently around 29% of spectrum is being shared between public sector and private sector users. The creation of a central public sector spectrum database that is dynamic and in due course accessible to the market (see paragraph 3.25 et seq), should permit visibility of potential sharing opportunities and allow more efficient and innovative use of spectrum going forward. New enabling technologies such as geo-location databases and white space devices will also add to this opportunity.

3.41. As part of the 500MHz public sector spectrum release works, we have made progress in enabling MOD to share more spectrum but further work is required before the plans can be fully implemented. MOD is in the process of preparing bands for sharing by progressing its technical preparatory work on bands identified for sharing. It has agree to share the 2025-2070MHz band with wireless cameras on a more formal basis than previously which will allow the makers of TV programmes reliant on wireless cameras to develop their business plans.

3.42. There are many examples of frequencies which are shared between uses and users today. For example, Programme Making and Special Events users, who generally require low power localised access to frequencies, are secondary users of spectrum assigned to broadcasters, and to the Ministry of Defence. There is considerable potential for generating more value from spectrum by increasing the amount of sharing that takes place.

3.43. Ofcom recently consulted on options for spectrum sharing[18]. It is already possible for users to agree to share spectrum, and to set the terms on which that happens – for example the Home Office uses MOD spectrum in places that the MOD does not require. We do not need a revised regulatory framework to accommodate licensed shared access. But where it is a question of finding frequencies that may be available on a time-limited and location-limited basis that changes relatively frequently, the position is more complex. Such "Dynamic Spectrum Access" is largely dependent on the geo-location databases for private and public sector use (see paragraph 3.25 et seq) – and the current regulatory framework does not provide well for such databases. We committed in Connectivity, Content and Consumers to amend the legislation to provide for this.

Incentive auctions

3.44. As we said in Connectivity, Content and Consumers, we want to make sure that we have the widest range of tools available to help get the best value from spectrum. We now have nearly 14 years of experience in running spectrum auctions, and we continue to believe that experience in the UK and elsewhere shows that a well-designed auction with well-informed bidders delivers the outcome most likely to deliver best value. However the amount of clear spectrum suitable for auction is limited. It may be possible to encourage more change of use through an auction process if there is some incentive to current users to release some, or all, of that spectrum. Currently all auction proceeds pass to the Exchequer. Allowing for some receipts to be retained by the releasing user might incentivise them to release.

[18] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

Working well together

4.1. An effective framework for spectrum use includes:

- Development of policy : the framework for how spectrum is allocated to different uses, managed and regulated; and
- Management and administration of spectrum assignments to individual users.

In this Chapter we set out how Government and Ofcom will continue to work well together to develop and implement spectrum policy, within the framework of EU and other relevant international law. We will also work with current and prospective spectrum users to make sure that spectrum policy is based on the best evidence available on developments in technology and international practice.

4.2. Overall responsibility for policy for spectrum, as for all else, rests with Government. It is the Government's role to ensure that the statutory framework for the management of spectrum is, and remains, fit for purpose. The conclusions of our most recent review of that framework were published in *Connectivity, Content and Consumers* in July 2013. We saw no need then for a significant overhaul of the arrangements which have been in place since 2003 for Ofcom to carry out management of spectrum, but we set out a number of proposed targeted amendments to improve spectrum management. These included making it easier for the Secretary of State to direct Ofcom on spectrum matters so as to implement broader Government policy. We used the power of direction in 2010 ahead of the 4G auction but with spectrum playing an increasing part in supporting Government policy we need to be able to work with Ofcom in a timely fashion.

4.3. Ofcom is a statutory body[19]. The legislation confers a range of functions on Ofcom in relation to the regulation of the communications sector (which broadly speaking encompasses telecommunications and broadcasting) and the management of radio spectrum. These include:

[19] Ofcom was set up under the Office of Communications Act 2002, with duties and functions relating to spectrum set out in the Communications Act 2003 and the Wireless Telegraphy Act 2006

- authorising use of spectrum (to implement the duties of the UK as a Member State under the Authorisation Directive);
- representing the UK and British Overseas Territories at the meetings of the International Telecommunications Union and the European Conference of Postal and Telecommunications Administrations (as directed by the Secretary of State in 2003 and supported by a Memorandum of Understanding between the Department and Ofcom); and
- providing expert advice to Government on public sector use of spectrum.

4.4. Ofcom's statutory functions make it responsible for authorising all use of spectrum in the UK, except for use by Crown bodies[20]. There are a number of statutory duties on Ofcom with which it must comply when carrying out radio spectrum functions. These duties include its principal statutory duty with respect to citizens and to consumers, which applies to management of spectrum as it does to Ofcom's other functions. Ofcom has a specific duty, when carrying out its spectrum functions, to secure the optimal use of spectrum for wireless telegraphy. Ofcom sets regulatory policies to achieve this through processes consistent with the EU Framework and Authorisation Directives.

4.5. Ofcom's functions and duties for managing spectrum clearly are fundamental to the success of our aim to elicit the best value for the UK from spectrum. As it exercises those functions, Ofcom must be fully aware of Government's wider policy objectives and the role that spectrum should play in delivering them. For its part, Government is responsible for deciding the role that spectrum should play in delivering that wider government policy. Government must consider spectrum policy alongside defence, transport, energy, security or other policies. Decisions on policies that depend on access to spectrum such as smart metering programme or the HS2 rail project are taken by Government, but advised by Ofcom. The emergency services rely on communications to function effectively, and the extent to which those services should in future depend on having a specific assignment of frequencies is a decision for Government. Once Government has decided that spectrum is required for public services, normal practice would be for that public service to be authorised to use specific frequencies in the same way as any other user – that is, they would ask Ofcom about options for spectrum to be assigned to them, or they would agree with another user some form of sharing/leasing arrangement, or they would acquire the frequencies from another user with that trade being notified to Ofcom. The Secretary of State can direct Ofcom to make frequencies available if necessary, such as the direction in 2012 to reserve frequencies for local TV.

[20] Figure 2 in Chapter 3 shows that Ofcom's authorisations currently apply to about 75% of spectrum use

4.6. The Government's policy on spectrum use is coordinated by the UK Spectrum Strategy Committee (UKSSC). It is co-chaired by senior officials from DCMS and Ministry of Defence, reflecting the role of DCMS as lead Department for spectrum policy and MOD's role as the Department responsible for management of most frequencies. The Devolved Administrations are members (spectrum remains a reserved matter). Ofcom attends as an observer, provides advice to the committee and takes account of the views of UKSSC when making its own decisions on spectrum matters within the UK. Current Terms of Reference are below.

To bring together all elements of Government, including Departments, agencies and statutory bodies, to co-ordinate policies and plans for the management of radio spectrum;

To oversee the development and implementation of the UK Spectrum Strategy, to scrutinise progress in realising the goals of the Strategy and to co-ordinate policies and plans which ensure its successful implementation;

To agree the allocation of radio spectrum through the UK FAT and to consider changes to it which meet the needs of users in both public and private sectors, with an emphasis on provision of vital services, generation of national wealth, national security and efficient use of available capacity

To agree positions and negotiating lines for relevant international fora, that have been developed by Ofcom and Government;

To work as appropriate with an industry-recognised spectrum forum; and

To report after each UKSSC meeting to the Minister responsible for spectrum policy on activities and decisions relevant to UK spectrum policy

4.7. The UKSSC will be the main body that oversees the development and delivery of this Strategy for Government. It will provide a forum for coordinating the views of Government and Ofcom in relation to implementing this Strategy. Given the number of organisations that have interests or holdings in public sector spectrum, it is important that all contribute to the debates around spectrum policy. The UKSSC will act as a coordinated, authoritative source of advice to Ministers, which listens to all interested parties, and thinks strategically as well as tactically, and which has the authority to take decisions on Ministers' behalf where appropriate. As part of the objective of ensuring consistent principles are applied to public sector and 'private' sector spectrum management, Ofcom will continue to attend the UKSSC meetings as an observer and contribute actively with its advice and experience.

4.8. The co-Chairs report the outcome of UKSSC discussions to the Minister responsible for Spectrum Policy who will consult colleagues on key issues as necessary.

International arrangements

4.9. The nature of spectrum is that in general frequencies can only be used by one party in a particular place and at a particular time without harmful interference. Use of spectrum is therefore highly regulated at a national and international level so that users do not suffer from harmful interference. This means that much of what we can do in the UK with spectrum is affected by changes at the international level. The UK must be a leader in promoting the best use of spectrum, supporting innovative applications and ways of maximising the value of this resource. The UK Spectrum Strategy will be flexible to reflect global developments and it will seek to influence them positively.

4.10. The International Telecommunications Union (ITU), an arm of the United Nations, organises the World Radiocommunications Conference (WRC) every three or four years as the key forum for agreeing the uses of spectrum bands. International agreements on spectrum are set out in the Radio Regulations, a global treaty negotiated at the WRC. The ITU also manages the process for coordinating the orbital characteristics and radio frequencies for satellites. The European Conference of Postal and Telecommunications Administrations (CEPT), a grouping of 48 European administrations, plays an important role agreeing Common European Positions in order to ensure a strong European voice at WRCs.

4.11. The EU also plays an important role. The assignment of spectrum is the responsibility of individual Member States and this should continue to be the case. Nevertheless, coordinated approaches to the management of spectrum by Member States can bring major benefits for consumers and help to support economic growth. Ofcom represents the UK on the EU's Radio Spectrum Policy Group, which assists the Commission in developing policy, and on the EU's Radio Spectrum Committee, which develops technical implementation measures. The EU Communications Committee and the European Council play a part in the legislative process and the UK is represented in these meetings by Government.

4.12. Some public sector use is governed and coordinated by other international bodies. NATO also has an important role, for example, in the allocation of international spectrum across Europe in harmonised military bands, such as 225 – 400 MHz where each nation has handed management responsibilities to NATO for the Air-Ground-Air portion of the band. The International Civil Aviation Organisation (ICAO) is the key coordinating organisation for aviation, and the International Maritime Organisation (IMO) plays a similar role for maritime interests.

4.13. Ofcom represents the UK in international spectrum discussions at the ITU, CEPT and the EU under a Direction from the Secretary of State. The Direction empowers Ofcom to make decisions and sign agreements on behalf of the UK. It is clearly important that there are robust and practical processes in place for ensuring

that the positions Ofcom takes fully reflect Government policy. This happens at a number of levels:

- There is ongoing informal consultation and discussion between Ofcom and government at working level and government officials attend key meetings of the ITU and CEPT alongside Ofcom.
- Officials from government departments, agencies and other statutory regulators attend and contribute to the working groups of the International Frequency Planning Group (IFPG), the stakeholder consultative groups chaired by Ofcom.
- Ofcom chairs the IFPG itself, which is attended by government departments, agencies and other statutory regulators and provides a platform for consultation with government. The IFPG does not take decisions but provides a sounding board for Ofcom to share its thinking on what UK policy should be and helps clarify and resolve issues where there are different views between government departments.
- Finally, at the most formal level, Ofcom brings its proposed lines for the UK's policy to UKSSC and asks Government to agree them.

Taken together, these processes ensure that the positions taken by Ofcom fully reflect Government policy. Although the Government retains the power to direct Ofcom to take a particular position in international discussions, this power has never been used.

4.14. Developing UK policy positions and negotiating lines on international spectrum issues is a complex and challenging task. UK policy often needs to balance a range of priorities and competing interests, it needs to be flexible and responsive to the positions of other countries, and it sometimes needs to take tactical positions as negotiations develop. It also needs to take into account UK interests in spectrum outside the UK for example the BBC World Service, UK Overseas Territories, Ministry of Defence activities. At the same time, it is important that the policy development process is open and participative, that stakeholders can understand the broad context of UK policy, and that all stakeholders' views can be properly taken into account in formulating UK policy. We will review the arrangements for IFPG after the next WRC in order to assess how well they have worked and whether changes could be made for the future.

ACTION: The Government and Ofcom will work closely together to ensure that the UK continues to have a strong, authoritative and influential voice in international discussions on spectrum.

Working with spectrum users

4.15. The development and implementation of spectrum policy by Government can only be effective if there is a sound understanding of what spectrum users are doing

and how their needs are changing. We welcome the creation of the UK Spectrum Policy Forum (SPF) which is open to all spectrum users[21]. The aims of the SPF should be to act as a sounding board for Government and Ofcom and to challenge them on the priorities for spectrum management. The SPF can bring together the latest intelligence and thinking, and should also be able to commission research to build the evidence base to support decisions on spectrum management taken by the UK and promoted internationally. The SPF should also provide access to supply chains supporting spectrum users, and so can help develop a multiplier effect to exploit innovation in applications in the public and private sector.

4.16. We want the SPF to be open to all, and not just to those who can afford a membership fee. We will consider how we can best support the SPF's work so that it can contribute effectively to implementing this Strategy.

4.17. We will take the views of industry, consumers and citizens into account when deciding on the key aspects of spectrum policy. Formal consultation will remain part of the process when Ofcom or Government are proposing to exercise their powers set out in legislation. However the SPF will help the UKSSC to recognise industry's views on critical matters at an early stage of policy development. For example, the UKSSC could invite the Chairperson of the SPF to provide its views on certain issues, in advance of or in addition to a formal consultation. The active engagement of the SPF in the discussion stages should make such consultations much better informed and lead to improved evidence-based decision-making.

4.18. To ensure that Government, Ofcom and spectrum users can together help to develop this Strategy, we will bring together the Minister with responsibility for Spectrum Policy, the Chief Executive of Ofcom, and the Chair of the Spectrum Policy Forum in the UKSSC Reference Group. This Group will advise the Minister on issues he may wish UKSSC to consider, including regularly reviewing the strategic priorities.

ACTION: we will work with the UK Spectrum Policy Forum to keep the Spectrum Strategy focused on the key issues for delivering best value for the UK from spectrum.

[21] http://www.techuk.org/focus/partnerships/item/180-uk-spectrum-policy-forum

Looking to the future: Spectrum's role in innovation and growth

General

5.1. Spectrum is an important catalyst for innovation and growth of the economy. Technological advancements over the last couple of decades have already transformed the way we use and view spectrum. However the nature of spectrum itself as a resource has not changed. It is finite and different parts of the spectrum are not interchangeable due to their differing physical characteristics.

5.2. Public policy must consider the implications of future technologies for management of spectrum. The development of new technology is defined to some extent by the potential availability of spectrum. Systems can almost always make use of spectrum more efficiently, but this is likely to increase the cost of products. There is a need to stimulate innovation in spectrum use and facilitate the development of technologies which reduce reliance on spectrum. At the same time, we must ensure that the development of new technologies which can contribute to our economy is not stymied due to unavailability of spectrum.

The wireless economy

5.3. Spectrum is a key piece of the infrastructure of the wireless economy. The mobile internet, which is expanding rapidly, is making dramatic changes to the way we live. Smartphones and tablets have inspired thousands of apps which take advantage of location and other data to provide services. These range from the convenient, to apps that facilitate commerce or even save lives. Use of these apps in turn generates data, which can be further refined to provide even more tailored products and services.

5.4. Mobile commerce too is growing rapidly. M-Commerce expenditure in the UK is expected to rise by 5 times in the next 5 years and make up 25% of all on-line expenditure in the same period. Businesses are quickly recognising that a presence in this wireless world is essential to survive.

5.5. As well as products and services driven by mobile data, machine to machine use (‘the Internet of Things’) is driving big changes in efficiency and productivity. McKinsey estimate that the mobile internet could generate between $4 and $11 trillion of global economic value per year by 2025. Similarly, machine to machine use could

have an economic impact of between $900 billion to $2.3 trillion by 2025 in manufacturing alone.

5.6. The growth of the wireless economy places huge demands on the availability of spectrum. By making spectrum available to our researchers and innovators, we stimulate innovation and can help set the frequencies and standards for new developments giving our industries a head start.

Technological developments

Ubiquitous Connectivity, 5G and Dynamic Spectrum Access

5.7. Many new developments rely on connectivity to make them work. Radio is an important part of this connectivity. We can expect to see systems offering similar availability of services to people on the move akin to what they expect in a fixed environment. This is often called ubiquitous connectivity. Developments such as 5G, Big Data, the Internet of Things, Machine to Machine (M2M) communications, Broadcasting, Cloud Computing, Internet access and Smart Cities will all use connectivity that is dependent on various forms of radio and fixed communications. These developments will be based on new and innovative forms of wireless communication. This will increase demand for spectrum which will be partially solved by making use of higher frequencies at present. But much of the demand will have to be satisfied by better use of existing spectrum. TV white spaces is a currently developing example of what is generically call Dynamic Spectrum Access (DSA). DSA is a technique where radio spectrum is used in a flexible manner. Spectrum is used in a controlled way for individual users, items of equipment etc, at a particular instant in time to give the connectivity required by that individual at that point in time. This gives the user the perception that they have an almost infinitely wide channel. As soon as it is not used by an individual it is then used for something else. A particular frequency may thus move from broadcasting to M2M to telephony etc. over a short space of time.

5.8. The concept of owning a particular piece of spectrum in a given region for your exclusive use will thus no longer the main way of operating. The use of DSA is expected to grow steadily from the latter part of this decade, but we would not expect all spectrum to be given over to DSA in one go. We may expect to see DSA and conventional spectrum being used in parallel for the foreseeable future. It is also possible that DSA might have several modes of operation. The spectrum landscape in 10 years or more may be composed of spectrum allocated in a similar manner to the present, working alongside several modes of DSA.

5.9. 5G is foreseen as the first major use of the DSA concepts. It may use exclusively DSA, or it may be a mixture of DSA and current spectrum allocation techniques. Although 5G will be a single system concept it will contain many different parts. Each one of which will be equivalent to a single service as we see them today. So for example it will provide the equivalent of mobile telephony facilities as well as

Wi-Fi etc. This will mean the convergence of both engineering concepts by which 5G will be constructed, as well as converging current business models, in ways in which they can all work harmoniously. The allocation of spectrum for 5G will be very much the glue that will hold this together. On the one hand spectrum must be allocated in a way that satisfies the art of the technologically possible, on the other it must allow currently quite diverse business models to cohere onto a new way of working that will be 5G.

5.10. 5G is likely to handle a wide range of differing needs. We have some M2M working that will need a few kilobytes of data on an occasional basis, on the other we have the need to offer a real-time video experience with demanding graphics. The spectrum needs of each of these types of communication are radically different but DSA as a concept is able to deal with them and provide the best use of the spectrum for each. But it needs to have a 5G infrastructure in place to actually happen and this requires an evolution of ideas, then design, then finance and building, from now until the expected rollout at the end of this decade.

Internet of things and Machine to machine

5.11. It is estimated that up to 50 billion devices will be wirelessly connected to the internet by the end of the decade. Machine-to-Machine (M2M) communications are a key driver of this increase as they link devices together over the internet.

5.12. M2M communications are about allowing machines such as utility meters, vending machines and cars, whose primary purpose does not require connectivity, to connect with other machines. Data transfer between machines is usually initiated without human intervention. M2M is a component part of enabling the Internet of Things.

5.13. The Internet of Things (IoT) involves adding connectivity to passive objects (e.g. a sensor in a streetlight that sends a message to the council when it needs to be changed) and the deployment of connected environmental sensors (e.g. remote temperature or pollution sensors). The IoT concept requires data from all the connected objects to be readily accessible by many different users (i.e. devices are connected to and accessible from the internet). When objects can both sense the environment and communicate with each other, they become tools for understanding complexity and responding to it swiftly. This has huge potential for efficiency in all areas of the economy. Information from several parts of the environment can be used to dynamically alter another part to ensure the best situation for the whole community. This feeds into the smart city concept.

5.14. These physical information systems are already being deployed. Microcameras shaped as pills can enter the human body and send back images to locate sources of illness. Remote satellites and ground sensors can collect data and send it wirelessly back to precision equipment to improve farming efficiency. Billboards can instantly assess the profiles of consumers and adapt advertisements accordingly.

5.15. In M2M and IoT some devices will be physically mobile (e.g. cars), whilst some will be stationary ("fixed"). Although both mobile and fixed devices could place demands on the networks used to provide mobile data services, fixed devices could also use wired networks or fixed wireless communications (including short range devices), depending on practicability, performance and cost.

5.16. From the perspective of spectrum management, compared to mobile broadband consumption, projected per-connection M2M data volumes are likely to be low. The machines involved in M2M communications may be in locations that are harder to cover by conventional mobile networks. This means that such M2M applications would particularly benefit from a relatively low capacity but ubiquitous coverage layer. Some uses will be safety critical and robustness of the communications link will be paramount.

5.17. The widespread adoption of M2M and IoT will take time, but improvements in underlying technologies are progressing. The technology has the potential to deliver some very significant benefits to society. The IoT & M2M communication comprise objects/things that are connected to the Internet, anything, anytime, anywhere. Furthermore, in IoT, any object can be a data source. This begins to transform the way we do business, running of the public sector and day-to-day life of millions of people.

Smart cities

5.18. A smart city uses intelligent technology to enhance the quality of life in urban environments. Cities can use the data in a variety of ways; to save money, minimise waste, measure domestic water usage and manage transport routes. Such transformation will be essential to address the challenges of rapid urbanisation by improving services and managing their efficiency.

5.19. Allowing the public access to real time information enables people to make more informed choices, such as planning a journey by checking for available room on trains and buses or even identifying car parking spaces before leaving the house.

5.20. For smart cities to become a reality a modern digital infrastructure is required, combined with a secure but open access approach to public re-useable data, which enables citizens to access the information they need, when they need it. Smart cities will also mean creating an intelligent physical infrastructure ("smart" systems or the Internet of Things), to enable service providers to use the full range of data both to manage service delivery on a daily basis and to inform strategic investment in the city/community (for example, gathering and analysing data on whether public transport is adequate to cope with rush hour peaks).

5.21. Research for BIS estimated that the smart cities industry could be worth more than $400 billion globally by 2020, of which the UK could gain a 10% share ($40

billion). The Government has convened a Smart Cities Forum, jointly chaired by David Willetts and Greg Clark, in order to help all parties to develop a shared perspective of challenges and needs, to understand the barriers to progress, and the priorities for effective Government intervention, in order to strengthen UK capability and practice.

5.22. In conjunction with developments in M2M communications and the Internet of Things, smart cities will also have huge implications for spectrum demand and usage. These needs are those discussed earlier in this section and will vary from application to application.

Setting direction

5.23. Our strategy is to manage spectrum with regard to stimulating innovation and growth in the UK. Spectrum is an invaluable tool for many new technologies and companies need to use spectrum for testing, research and development before their products are commercialised.

5.24. Ofcom enables technical testing of new uses of spectrum through the granting of non-operational licences[22]. As set out in the Information Economy Strategy, Government has asked Ofcom to take this further by investigating the creation of an automated online geolocation database aimed at providing on-demand, short term spectrum licences for research and development (R&D) into 5G and other advanced communication systems. In August 2013 Ofcom published its consultation on this proposal in the context of broader innovative proposals for sharing spectrum[23].

ACTION: we will continue to ensure that spectrum is available for research to stimulate innovation and growth.

5.25. Our intention is for the next generation of mobile technology to be developed here. Over £50 million of research funding has been secured for the new 5G Innovation Centre at the University of Surrey and a consortium of mobile operators and infrastructure providers from around the world will be working there. This centre will establish the world's first live operational test bed for 5G technologies and services, putting us at the forefront of influencing and informing new global standards in 5G.

5.26. This new state-of-the-art global research facility should be the catalyst for a nationwide effort to achieve our ambition to be a world leader in the development of 5G technology. To do that we need to encourage UK academia and industry to fund research into 5G and to ensure that technology companies large and small across the

[22] http://licensing.ofcom.org.uk/radiocommunication-licences/non-operational-tech-licence/

[23] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

country are able to conduct 5G R&D. This will ensure that we have a good selection of ideas to feed into global discussions on what 5G will look like.

ACTION: we will facilitate the development of advanced communications technologies and ensure the availability of suitable spectrum and other mechanisms wherever possible.

5.27. Under the Information Economy (IE) Strategy government and industry have agreed a series of aims for this sector in the UK. As part of this an IE Council has been created to enable these aims to be realised. A Future Technology working group is looking at the technology needs part of this. A detailed study is currently underway on the strengths and weaknesses of this technology area of the IE sector in the UK and what areas we should develop in future. This will be evaluated by the Council and will inform our management of the spectrum to maximise spectrum availability to support future developments. Industry has set up the Spectrum Policy Forum (SPF) to act as a single point of contact with government for their spectrum needs in the future. IE Council work will take note of spectrum needs highlighted by the SPF.

5.28. If the UK intends to get the best value from spectrum in the next 10 to 15 years, the strategy must be reviewed and refreshed on a regular basis. Working with Ofcom and the Spectrum Policy Forum we will keep the strategy up to date and reflective of the needs of users.

ACTION: We will respond to industry and foster study and take up of new technologies.

5.29. Much of what we can do in the UK with spectrum is governed by changes at the global level. We want the UK to be a leader in making the best use of spectrum, supporting innovative applications and ways of maximising the value of this resource. We recognise that the World Radiocommunications Conference (WRC) should continue to be the key forum for agreeing changes to primary uses of spectrum bands globally while maintaining protection for key services such as defence. The UK Spectrum Strategy should be flexible enough to reflect global developments and to influence them positively, while maintaining the proper ability to take decisions nationally on changes of use within the UK.

5.30. The WRC is clearly not the only important factor influencing the UK's spectrum strategy. Through UKSSC we will keep the Strategy and progress in delivering the Actions identified under review. However from time to time we should also undertake a more strategic review. We will do this within one year of the conclusion of each WRC or sooner if appropriate (for example if the period between WRCs is more than 3 years).

ACTION: we will review the Spectrum Strategy within twelve months of the conclusion of each WRC and update it as appropriate.

Looking ahead

5.31. The following timeline shows some of the key events that will shape the future use of spectrum in the UK.

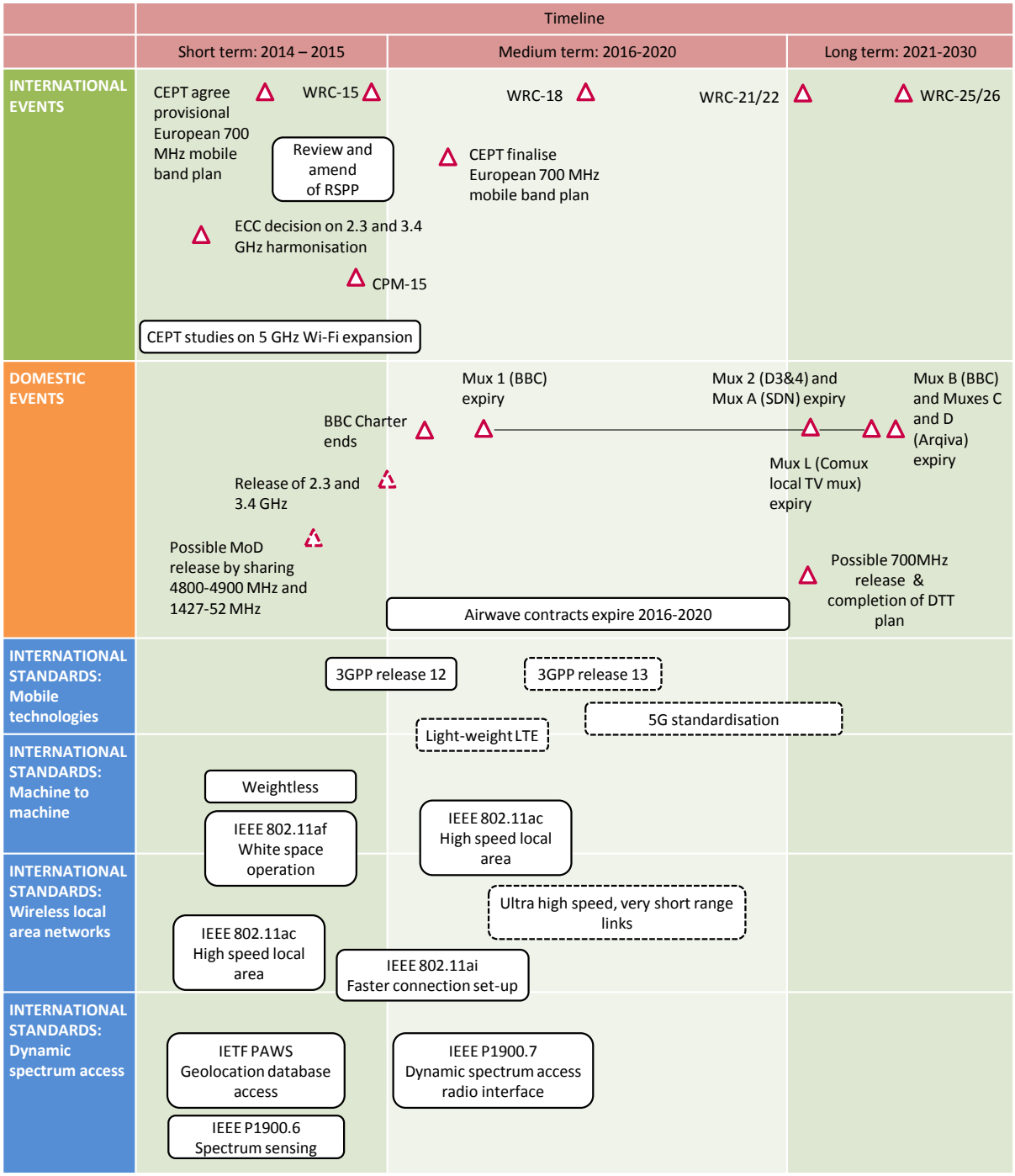


Figure 4: Timeline of key events for future spectrum use in the UK

Appendix 1 – Actions

1. We will develop a consistent methodology for assessing the full value of spectrum to the UK. To help us in this work we will invite a panel of experts to advise on options, and we will publish our conclusions by July 2015.

2. We will apply the same principles for valuing spectrum use across all sectors.

3. In order to make sure that the incentives to make best use of spectrum fall on those who can best respond to them, we will set out clearly by March 2015 the assumptions and mechanisms by which Government Departments will pay for the spectrum which they need, release the spectrum which they do not need, and be able to acquire new spectrum for future needs.

4. We will develop a single source of information on spectrum managed by the public sector which clearly identifies what frequencies are in use at what geographic locations, and hence what frequencies are available for use. This will enable the public sector to manage its spectrum more efficiently, and provide a database to underpin the determination of the charges which each user should pay for their use of spectrum.

5. We will ensure that this public sector spectrum database can interface with geo-location databases established by or authorised by Ofcom. This will enable in the future any potential user of spectrum to interrogate an up-to-date database of spectrum availability, and to identify who is responsible for agreeing terms for use of such spectrum.

6. Public sector spectrum releases will be planned in line with releases of commercial spectrum by Ofcom and taking into account international allocation decisions.

7. Public sector sales of clear spectrum will be handled by Ofcom.

8. The Government and Ofcom will work closely together to ensure that the UK continues to have a strong, authoritative and influential voice in international discussions on spectrum.
9. We will work with the UK Spectrum Policy Forum to keep the Spectrum Strategy focused on the key issues for delivering best value for the UK from spectrum.

10. We will continue to ensure that spectrum is available for research to stimulate innovation and growth.

11. We will facilitate the development of advanced communications technologies and ensure the availability of suitable spectrum and other mechanisms wherever possible.

12. We will respond to industry and foster study and take up of new technologies.

13. We will review the Spectrum Strategy within twelve months of the conclusion of each WRC and update it as appropriate.

Appendix 2 – the changing needs of the public sector

Aviation

To deliver interoperability and safety on a global basis, aviation is subject to regulation and technical standards set by the International Civil Aviation Organisation (ICAO) and on a regional basis by requirements laid down in European legislation. Aviation is dependent on spectrum to support the Communications, Navigation and Surveillance systems necessary to ensure safe and efficient flight. As such this spectrum is coordinated and managed on an international basis to maximise efficient use and meet increasing demand. This is exemplified in Europe through the regulatory requirements placed by the EC on States to ensure spectrum use is fully coordinated in support of the Single European Sky (SES) programme. The CAA acts as the National Frequency Manager in this context to ensure that UK aviation requirements are met in accordance with international processes. At both the global and European Regional level, spectrum strategies are being developed to ensure a consistent and efficient approach is taken to meet the growing demand for spectrum to deliver the technology improvements which deliver safety and capacity benefits. Aviation recognises that it needs to use technology improvements to meet this demand rather than always seeking more spectrum through the ITU process – an example is in voice communications where new radio standards for VHF have been introduced that reduce the frequency separation between channels and so significant increase capacity. However, because of the need to introduce technology changes for all users, and potentially on a world-wide basis, lead time to introduce new standards are of necessity very lengthy with 7 years notice of requirement normal. Added to this is the timeframe necessary to actually implement what are frequently costly and complex changes for the aircraft and ATC operators. Within the Government spectrum release objective, aviation is taking a proactive role through a programme to use emerging surveillance technologies to deliver ATC services in a way which uses less spectrum and could thus contribute to the target of releasing 500MHz. This is a complex work stream by DfT and CAA and has implications for other users such as MOD, MCA and Met Office. However, the UK is leading this work which could have significant benefits for aviation in Europe.

Defence

Just as Aviation must deliver interoperability on an international basis, so must defence and security. For example, the work of the Armed Forces delivering a large amount of short notice security at the 2012 London Olympics relied on a wide range of forms of spectrum dependent personal communication. The MOD also shared a large part of its communication spectrum with the police and is repeating a similar exercise for the Commonwealth Games in Glasgow this year. Additionally, at the same time as MOD is looking to release some spectrum, it is experiencing an increasing number of new demands for spectrum, particularly at a time when manpower is reducing and the hi-tech equipment than enables the Services

to operate with reduced numbers is becoming ever more spectrum reliant. Balancing these competing demands requires careful prioritisation, planning and preparation. Value to society as well as the market place must be taken into account.

Emergency services

The emergency services rely on several radio technologies and frequency ranges to provide them the essential communications capabilities they require to keep this country and its citizens safe, to provide rescue services, catch criminals and reduce crime and the fear of crime. No one single radio service or technology meets all the needs of the emergency services currently. Although the basic communication needs remain fairly static over the years, the landscape is ever evolving and the wireless services used need to evolve over time to ensure our capabilities are one step ahead of criminals. These changes need to be done taking into account the potential changes in the way the emergency services operate while supporting wider governmental objectives. For example, recently work was started to support the 190MHz MoD spectrum release. The target is to vacate over 70MHz of related spectrum from police use by moving video services that were sharing these bands elsewhere. Once the migration is over, while still sharing MoD spectrum, these services will be using spectrum with more spectrally efficient equipment and adopting better coordination practices to operate with reduced bandwidths. This brings financial benefits of lower spectrum costs for the Home Office.

Also other ongoing work, e.g. the Emergency Services Mobile Communications Programme[24] replacing the services provided by Airwave, is heavily focused on sharing resources where possible and minimising the spectrum footprint where dedicated spectrum is required to provide the necessary radio communications to the emergency services.

Smart meters

The Government's vision is that by the end of 2020 every home in Great Britain should have a smart energy meter and be using it to manage energy consumption. The roll-out of smart meters will unlock significant benefits for consumers and put them in control of their energy use, allowing them to adopt energy efficiency measures that can help save money on their energy bills and offset price increases.

Through the roll out we expect to see accurate bills, smoother and faster switching between suppliers as well as innovation in products and services that use the smart metering system to help consumers manage their energy demand and bills. Smart meters are also a critical step platform for the development of smart grid and demand-side measures.

The smart metering roll-out will result in the installation of (largely from 2015) some 53 million meters, together with an In-Home Display and communications hub, involving visits to some 30 million homes and businesses. The latest Impact Assessment estimates an overall net benefit to Great Britain of over £6 billion.

The Home Area Network is at the heart of the smart metering system, providing a secure wireless communications link for data between the smart meter and communication hub, In

[24] https://www.gov.uk/government/publications/the-emergency-services-mobile-communications-programme

Home Display and other consumer devices (e.g. devices which enable smart appliances and smart grid technology) within the premise. The roll out of smart meters in GB will therefore require the availability of a stable interoperable radio HAN solution that will continue to work for the lifetime of the smart meter system. Government has said that deployments can take place in licence exempt spectrum at 2.4GHz and 863-870MHz, noting the potential of any licence exempt spectrum at 870-876MHz. Relevant standardised communication protocols based on open standards are now being developed to enable the roll out.

The Wide Area Network also relies on spectrum and is provided by two communication service providers using different technology solutions. It is the means by which data is transmitted from the HAN through the communications hub to energy suppliers, network operators and other parties contracted to the central Data and Communications Company.

Meteorology & climatology

The monitoring of our environment, weather and climate is an essential global activity and coordination of activities and exchange of data is governed through the UN executive body responsible for such matters, the World Meteorological Organisation (WMO). The Met Office, as the UK's National Meteorological Service and representative to WMO, is responsible for providing a wide range of weather forecast and warning services to the public, emergency responders, defence, aviation and a range of other stakeholders across Government and industry. Reliable access to key radio frequencies is vital for the remote sensing and communication of the global environmental data upon which operational meteorology and the monitoring of climate change depend. Indeed, almost all of the observational data that is received and used by the Met Office involves the use of the radio spectrum, with examples including data from meteorological satellites, weather radar, radiosondes, ocean buoys and windprofilers - all of which needs to be coordinated within internationally agreed spectrum bands to ensure protection globally. Services based on the use of spectrum to obtain business-critical data underpin the protection of life and property (e.g. flooding, severe weather), building on the application of world-leading science and supercomputer modelling techniques. Indeed, with the growing challenges of climate change and the need to ensure that Met Office projections upon which key policy decisions will be based are as accurate as they can be, it will be ever more important over the coming years to ensure that both terrestrial and space-borne environmental monitoring based on spectrum access is both preserved and (where technology demands) enhanced. As such, the dependence of meteorological and climatological activities on access to spectrum is set to continue and even expand going forwards, especially with respect to continuing innovations in satellite-borne remote sensing technologies.

Satellite telecommunications

The satellite sector relies on continued and equitable access to orbital spectrum resources in order to maintain current services and to grow to a £40 billion industry, by 2030 and to generate 100,000 new highly skilled jobs. Long term spectrum regulatory support as well as improvements and innovation in spectrum efficiency will be needed to support this growth and for the UK to retain its market leading position, thereby maximising the benefit UK society and the economy. This large growth is likely to lead to much more extensive use of current allocations, further improvements in spectrum efficiency and potentially the search for new allocations. The introduction of new technology, finding enough bandwidth for affordable satellite broadband, changes to spectrum allocations and changes to filing procedures giving rights to orbital slots will be a challenge in the coming years.

The sector is by nature a global business, a satellite in geostationary orbit can "see" around a third of the surface of the Earth and this means there is a need for global spectrum allocations, with compatible technology and for international coordination and engagement. As this a private sector industry, in order to raise the capital needed to invest in the future through the markets, satellite operators need to be sure the key satellite broadcasting, telecommunications and mobile satellite bands between will be available for the long term. Satellites are not an easy technology and the development cycles are longer than for most terrestrial services and it is important for regulators to take a long term view, even if in the short term this leads to spectrum not being fully utilised. A large telecommunications satellite typically represents an investment of several £100 million with a build-launch-service cycle covering 15-20 years.

The pace of innovation in the use of spectrum by the satellite sector is speeding up. The expansion of services into the higher frequency bands around 20/30 GHz has been supported by the existence of a long standing spectrum allocation. The need to expand satellite use into these bands was foreseen in the 1970s but widespread use has only emerged relatively recently. Without the long term vision and support for the allocation by the UK regulator acting within the ITU, it is likely that the current and future benefits would not be realisable. Avanti, a new UK based satellite operator have recently raised £500 million of capital to finance their fleet of Ka-band (26.5-40GHz) satellites, now in service and delivering affordable access to satellite broadband in remote and not so remote regions, contributing to both the upstream and downstream satellite markets and generating significant export revenues. Inmarsat is another example of a UK satellite company developing more efficient use of the spectrum. Inmarsat's traditional business in providing moderate rate data links to pretty much anywhere in the world using L-band spectrum at 1-2GHz, is well known and extensively used. Higher bandwidth services are being developed through Inmarsat global Xpress with each satellite providing 89 spot beams using the 20/30GHz band. Inmarsat in collaboration with ESA have also launched a next generation L-band satellite, Alphasat which carries an 11metre dish antenna to permit extensive L-band frequency re-use via spot beams, this satellite is also trialling Laser based communications and the 40/50GHz band.

Space/science

Space science makes extensive use of spectrum and there are many challenges, mainly due to the need to find spectrum for new services. Science applications often have a high sensitivity to interference.

For example, radar satellites imaging the earth are frequently looking for very small changes in the environment. There are several bands available to this application and there are good reasons for using spectrum in these regions. Low frequencies are good for penetrating into materials, measuring the bulk properties, for example vegetation and snow and ice. Higher frequencies generally give returns from the surface, which are good for imaging. The C-band (4-8 GHz) is especially valuable, in this region of the spectrum returns are mainly from the surface of objects and the propagation environment is most benign, with fewer of the ionospheric effects that can disturb lower frequency measurements and good resilience to absorption by clouds and rain which is especially important in tropical regions, for example in monitoring rainforests. This facilitates stable repeatable measurements with good contrast; these are properties vital for interferometry and support the widest range of applications in Agriculture (land cover, crop type/condition/yield), Forestry (management, deforestation etc), Geology, Hydrology (flooding, soil moisture, snow and ice fields, avalanche, rivers & lakes, wetlands), Oceans (shipping and surface winds, sea ice, icebergs, coastal erosion). The

example image shows how the effect of the construction of the Jubilee line has resulted is an average rate of subsidence of 7mm per year in the surface above, these are very fine, long duration measurements that are close to the threshold of what is achievable.

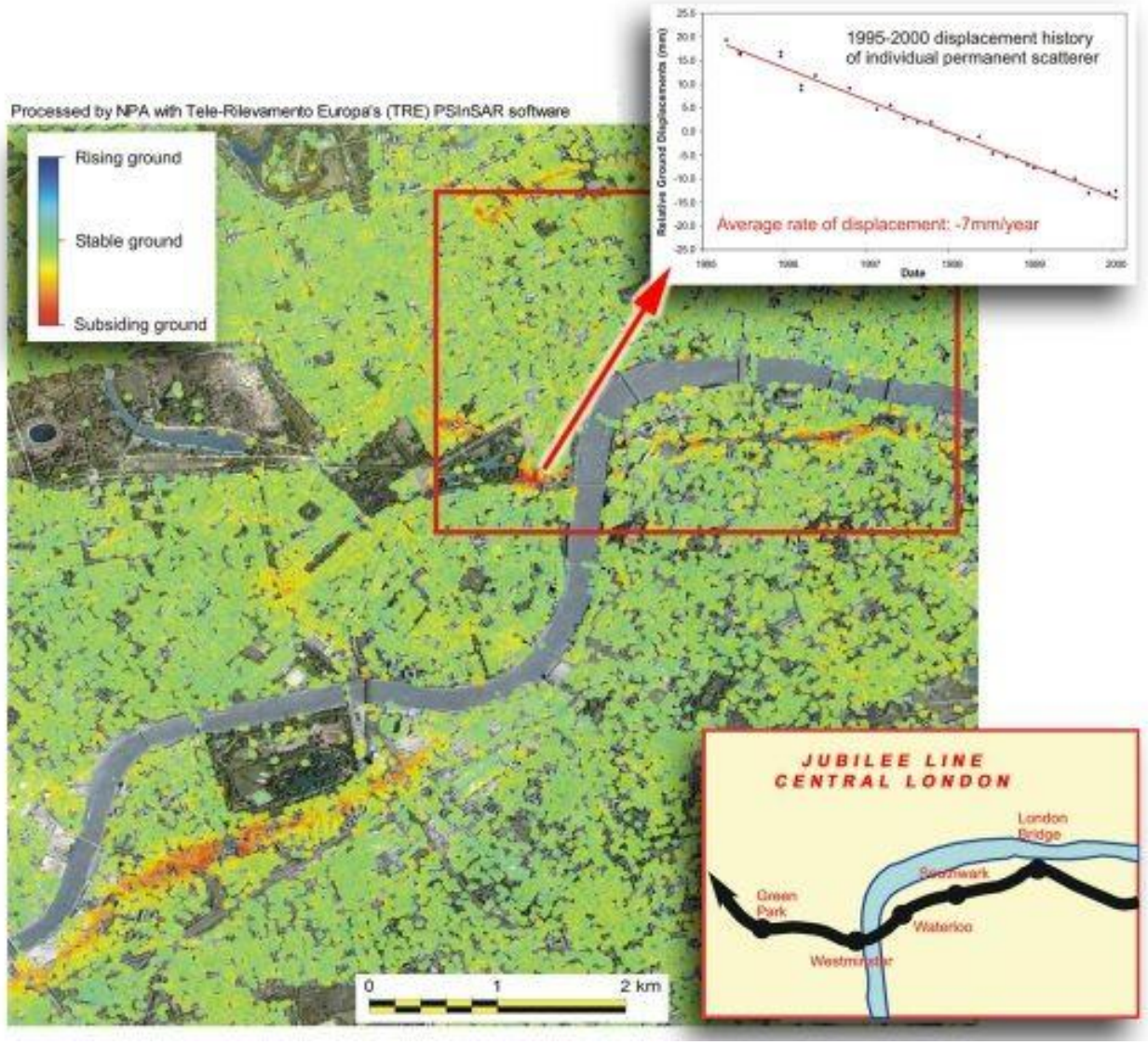


Figure 5: Image of subsidence beneath Jubilee Line tunnel as imaged using Synthetic Aperture Radar (SAR)[25]

Interferometry measures the difference in the reflected SAR signal over time. These differences are small and the useful information is contained in the tiny differential signal which is orders of magnitude lower than the already low SAR signal, and is very sensitive to interference. Often the interference may not be detectable leading to inappropriate subsequent actions being taken. The challenge for the future spectrum management is the protection of these services and of similar space science applications, while also allowing other services to share the spectrum.

[25] NPA Satellite mapping for ESA (2002), http://earth.esa.int/psic4/background.html

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