Study for the European Commission

Final Report:

Optimising the Public Sector's Use of the Radio Spectrum in the European Union

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1 Introduction

This is the Final Report of a study that has been conducted on behalf of the European Commission: *Optimising the Public Sector's Use of the Radio Spectrum in the European Union*. The objective of the study was to develop a better understanding of the use of spectrum by the public sector and to explore ideas for improving the efficiency of spectrum allocation, assignment and use to and by public sector organisations.

More efficient and effective use of radio spectrum by the public sector could produce multiple benefits, including:

- More effective delivery of services by the public sector;
- Improved socio-economic performance of the private sector to the extent that spectrum currently used exclusively by the public sector might be either freed or else made available for sharing;
- Increased speed and administrative efficiency in responding to spectrum needs that change over time.

Section 1.1 of this Introduction provides the goals of the study. Section 1.2 discusses the role of the European Commission in spectrum management. Section 1.3 explores the challenges of spectrum management in the public sector in general. Section 1.4 reviews our methodology. Section 1.5 presents the organisation of the balance of the report.

1.1 Goals of the study

A core, threshold question for this study is, what exactly is it that we are seeking to optimise? *Economic efficiency* is clearly important, but it cannot be the only measure of success – the allocation mechanisms must support demanding public sector applications, many of which are essential to the protection of life and property. We choose instead to refer to our central objective in the study as one of optimising *socio-economic efficiency*. We do so with an eye to a distinction that many in the field draw between the *efficiency* and the *effectiveness* of spectrum allocation in the public sector, where effectiveness refers not only to productive efficiency (see below) but also to being *fit for purpose* in the sense of enabling the public sector spectrum user to properly perform its mission.

The concept of socio-economic efficiency has three aspects:

- Productive efficiency: goods and services are produced at least cost assuming output and technology are fixed;
- Allocative efficiency: resources are allocated in such a way as to maximise economic and social well-being at a given point in time; and
- Dynamic efficiency: economic and social well-being are maximised over time through investment and innovation in the supply of goods and services.

The public sector is a very substantial user of European spectrum (with assignments representing 40-50% of the valuable frequencies below 15 GHz); consequently, obtaining greater operational performance and economic/societal value per unit of spectrum employed could potentially improve public service delivery, in addition to having a positive impact on the overall European economy. Inasmuch as the public sector users in question play an important role in the European economy, any improvement in their socio-economic efficiency can play a significant direct positive role, and can also generate substantial economic spill-overs. For example, the defence sector in Europe spends more than € 200 billion per year, representing some 1.78% of European GDP, and employs just under two million military and half a million civilians.[1] Maritime transport (including both sea and inland waterways) employs 223,000 in the EU27, and represents 89 billion euro of annual turnover; air transport employs 392,000 in the EU27, and represents 111 billion euro of annual turnover.[2]

More socio-economically efficient use of spectrum by the public sector can contribute in important ways to the achievement of the Lisbon Strategy that was promulgated in 2000. The Lisbon Strategy is a development plan that seeks to make the EU the most dynamic and competitive knowledge-based economy in the world by 2010, and in doing so to generate sustainable economic growth, more and better jobs, and greater social cohesion.[3] Better use of spectrum by the public sector can contribute to the achievement of these goals not only by making the public sector more efficient, but potentially also by making unneeded spectrum available to stimulate the growth of the non-public sector.

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1 European Defence Agency, "European Defence Expenditure in 2006", Brussels, 19 November 2007. These figures correspond to the 26 Member States that participate in the EDA.

2 European Commission (DG TRAN), *Energy And Transport In Figures 2007*. These are estimates of 2005 activity based on Eurostat data (economic activity according to NACE Rev.1 classification). See also http://ec.europa.eu/research/transport/transport_modes/water_en.cfm#, which claims that more than three million people work directly in the European maritime sector and generate a turnover that is also about € 200 billion per year.

3 See "The Lisbon strategy for growth and employment: Report from the High Level Group chaired by Wim Kok", November 2004, available at: http://ec.europa.eu/growthandjobs/pdf/kok_report_en.pdf

Specific topics that the Commission has identified as being of interest are:

- How to find the appropriate balance between commercial activities (both licensed and licence-exempt) and the public sector;
- The degree to which it might be beneficial for EU Member States to develop a more market-oriented approach to the use of spectrum;
- Possible improvements in the procurement processes that public agencies use for devices and services, both in terms of efficient allocation and in terms of interoperability; and
- The relevance of technological improvements to more efficient use of spectrum, greater sharing, enhanced interoperability and economies of scale.

The Commission asked us to focus on three specific areas of public sector use:

- Defence;
- Emergency services; and
- Transport (especially aeronautical and maritime).

These areas account for the majority of public sector spectrum use (see Chapter 2).

1.2 The Commission's role in the management of spectrum

The European Commission plays a central role in promoting the Lisbon Strategy (with its emphasis on growth and jobs in Europe), and in achieving the Single Market. Spectrum is a scarce and valuable resource where, for both economic and technical reasons, there could be benefits from some degree of enhancement and harmonisation of policy at the European level.

The Commission plays a significant role in the harmonisation of the allocated use of specific frequency bands across the European Union. Potential benefits from the harmonisation of spectrum allocations flow primarily from (1) economies of scale and scope in equipment manufacture and service provision, (2) interoperability of services across all Member States, and potentially with other countries, to the extent that the same equipment can be used to support and access services, and (3) reduced risk of harmful radio frequency (RF) interference.

Beyond its role in harmonising spectrum allocation, the Commission has undertaken a range of activities to enhance the effectiveness of national management of the radio spectrum by appropriate collaboration at European level.

To date, the majority of the Commission's initiatives in regard to promoting and coordinating best practice spectrum management have primarily addressed either licensed commercial spectrum use, such as by mobile operators, or licence-exempt or collective use. A balanced EU radio spectrum policy also requires adequate consideration of the spectrum requirements of the public sector, even though much public sector use falls outside of the legal and institutional competences of the European Community.

In calling for this study, the Commission has emphasised its commitment to working with national stakeholders and sectoral regulatory bodies to facilitate the introduction of improvements in the current situation. The Member States have also been interested in improving the socio-economic efficiency of use of spectrum by the public sector, and have been studying substantially the same issues through their representatives to a special working group (*Public Use of Spectrum*, or *PUS*) of the *Radio Spectrum Policy Group* (*RSPG*). The European Commission has expressed its desire, with the utmost consideration for national competences and specific sensitivities in this area, to launch a dialogue with National Administrations of the Member States to define approaches needed to assist their public sector operators to use spectrum more efficiently.

1.3 The challenge of spectrum use by the public sector

Spectrum policy for public sector spectrum users has historically differed from that relevant to commercial and private users. There are four primary factors that engender special challenges to spectrum management in the public sector: 1) the critical importance of many of these public sector uses (including the defence, transport, and emergency services), and a corresponding disinclination to rein in these services, coupled with challenges in valuing in monetary terms the societal benefits that they offer; 2) the variable and unpredictable nature of some public sector uses; 3) the long term reservation of spectrum for specific services and the absence (in many cases) of market and financial incentives encouraging economically efficient allocation, assignment, and use; and 4) the necessity of government serving as an impartial *arbiter among competing demands* for radio spectrum at the same time that government is itself a significant *user* of radio spectrum, with its own demands for spectrum.

In the remainder of this section, we consider each of these four aspects of the management of spectrum that is used by the public sector.

1.3.1 The criticality of spectrum used by the public sector

Many of the public sector activities that we are studying – defence, public safety, and aeronautical and maritime transport – are *essential to safety of life*. More generally, the high social value of public sector spectrum allocations is due to the direct linkage to

national security, law enforcement, health, transportation, and safety. Government decision-makers have been understandably eager to ensure that these services operate reliably and well. This has translated into a desire that public sector users have ample spectrum, and that the risk of harmful interference be very low.

As regards the volume of spectrum, public sector spectrum allocations amount to as much as 40% of the (extremely valuable) spectrum between 108 MHz and 3 GHz, and as much as 50% of the allocations below 15 GHz. This is partly for historic reasons, inasmuch as all spectrum was originally under public sector control;[4] the commercial use of spectrum is a relatively young trend. Still, we can infer from the large volume of spectrum allocated that governments ascribe a high social value to public spectrum use.

The need to avoid harmful interference to these vital services, not only within national borders but also across them, has led to extensive international harmonisation of spectrum allocations, notably for bands associated with aeronautical and maritime transport. This tendency has been reinforced by the need to achieve economies of scale, and to use equipment in more than one country. Again, governments have understandably taken great pains to ensure that the risk of interference to these critical services was suitably low.

Growing demands for spectrum resources from both public and private sector users have begun to put pressure on these practices. Public sector use potentially denies use by commercial and other private activities which may also generate economic and social value. For that matter, one use by the public sector potentially denies use to other activities in the public sector.

The reason that this is of concern is that public sector spectrum use is not subject, in general, to systematic or periodic review (in most Member States) to ensure that the spectrum assignments are still needed, and are no larger than necessary for technologies available today.

1.3.2 The variable and unpredictable nature of utilisation rates

The utilisation rate of public spectrum ranges from near constant (e.g. some radar systems) to mostly idle (e.g. some emergency communications systems). For example, spectrum use by defence and emergency services is often intermittent and unpredictable making it difficult to determine the "right amount" of spectrum they should be allocated. There are also security issues associated with access to information about spectrum use by these services, making it difficult to scrutinise whether existing use is appropriate or not.

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4 Martin Cave, et al, "Is public sector spectrum management different?", in *Essentials of Modern Spectrum* (Cambridge University Press 2007).

On a cursory analysis, spectrum allocated to emergency communications may appear unused because carrier waves in the band are not being utilized at any given moment; however, this spectrum is merely idle, not unused. The spectrum is providing the benefit that it *could be* instantly available should an emergency arise. Such options have intrinsic value, even though the option may rarely be exercised; however, the value of the option is nearly impossible to calculate. On the one hand, the opportunity cost of the idle spectrum is the foregone benefit of using it for alternative current communications. On the other hand, the benefit of the idle spectrum is the expected value of having reliable, secure and immediate access to wireless communications should an emergency arise.[5] The monetary value of public sector spectrum use is difficult to assess, but it is clear in some cases that the social value is high.

Typically, the need for reliable, secure and immediate access to spectrum has been met by means of permanent, exclusive spectrum assignments. A topic that we take up in Section 3 is the degree to which new technologies might provide the public sector user with intermittent high priority pre-emptive spectrum access in bands that are otherwise assigned to other users.

1.3.3 Long term spectrum reservation and a possible lack of incentives for economically efficient allocation, assignment and use

Spectrum allocation for the public sector faces particular challenges in terms of maintaining efficiency of use. There are two aspects of efficiency that are relevant here: 1) whether the amount of spectrum allocated to the public sector is optimal from a social perspective in the sense that it maximises the economic and social benefits from spectrum use and 2) whether the public sector user is deploying technologies that make economically efficient use of the spectrum taking due account of equipment costs and the value of the spectrum occupied.

Concretely, public sector frequency management typically differs from that of the private sector in four key respects:

- Spectrum allocated and assigned to commercial and private users is usually managed by the spectrum management authority, but spectrum allocated and assigned to public sector users is often allocated to governmental bodies (e.g. Ministries) that in some cases manage their own assignments.

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5 The consequences of not having reliable, interoperable emergency communications can be catastrophic. Numerous New York City fire fighters perished in the September 11th attacks because their radios were not capable of receiving the order to evacuate the World Trade Center. See The *Final Report of the National Commission on Terrorist Attacks Upon the United States* (9/11 Commission Report) at 297 - 302.

- Private sector users typically have licences of fixed duration, which do not have an automatic presumption of renewal; public sector users by contrast often have long term exclusive spectrum reservations, typically with no end date.

- Commercial and private use is licensed while public sector use often is not.

- Commercial and private use is usually publicly documented. By contrast, there has been little public transparency concerning decisions over public sector allocations, and even the spectrum management authority in some countries has little information on actual spectrum use (partly for security reasons).

These differences have important implications. Assignees tend to view spectrum assignments as permanent and, in most cases, costless. This tends to mean that the efficiency of current use is rarely challenged. It may also create a perverse incentive for public sector organizations to seek spectrum resources beyond their needs for current use, holding spectrum for the possibilities of future use. More generally, public sector agencies may not face sufficient incentives to make maximally economically efficient use of their spectrum assignments (e.g. through sharing with other compatible uses), or to give spectrum back to the spectrum management authority if they no longer need it.

Spectrum licensed for commercial use in Europe, by contrast, is generally assigned through the use of competitive mechanisms such as auctions, and the Commission has recommended that they be increasingly subject to trading in a secondary market after initial assignment. These market-based mechanisms tend to promote economically efficient use, not only by getting radio spectrum into the hands of those who value it most, but also by motivating commercial entities to make efficient use of a resource for which they have paid substantial sums. In addition, technically efficient use is often imposed through administrative policies applied to the commercial sector (e.g. through requirements for particular channelisation, modulation and link lengths). For collective and/or licence-exempt use, technological mechanisms help to maintain efficiency, as witnessed by the rapid improvement in performance and capacity of wireless local area networks since their introduction.

A key question for this study is the degree to which the differences between private sector and public sector spectrum management are justified, and if they are not how the specific challenges posed by public sector spectrum use could best be addressed. In particular, should public sector users should face stronger incentives for more economically efficient spectrum use? As we discuss in later chapters, the reforms required in order to achieve more efficient use might extend well beyond spectrum policy into other areas of public sector management.

1.3.4 The complex role of government as both a manager and a user of radio spectrum

Some public sector users manage their own spectrum allocations with little if any involvement of the spectrum management authority, while others have their allocations managed by the spectrum management authority. Complexities arise in both situations.

Where the public sector user manages its own allocations – as is often the case with defence for example – there may be little or no external scrutiny of the efficiency or effectiveness of its management activities. In these circumstances, the user/manager has few incentives (apart from quantity constraints) for efficient or effective use of the resource. This problem is particularly acute where the necessary information on spectrum use and management cannot be shared with third parties (such as other government bodies) for security or safety reasons.

Where the spectrum management authority manages public sector spectrum use, conflicts of interest may arise, because the spectrum management authority represents a Member State government with its own interest in the use of radio spectrum. To the extent that the government (of which the spectrum management authority is a part) has its own interests as a user of radio spectrum, it may be difficult for the spectrum management authority to be truly impartial and objective in its judgments. In particular, when the spectrum management authority is called on to judge between public and private interests, there might well be a tendency toward bias in favour of government interests. Phrased differently, the spectrum management authority might not be motivated to hold government users to the same high standards to which it holds private sector users. Addressing these potential conflicts of interest might represent another opportunity to improve the efficiency and effectiveness of spectrum use by the public sector.

1.4 Methodology

A key component of this study is an analysis of the current situation in respect of public sector spectrum in the EU and relevant non-European countries with an eye to identifying and suggesting remedies to policy shortcomings. The information used in this analysis came from three main sources: (1) desk research, (2) interviews with stakeholders, and (3) input from the first of the two public workshops.

Our desk research comprises a combination of data collection, policy analysis and spectrum audits using a variety of sources. We have drawn on the growing body of literature that addresses ways of improving public sector spectrum use and the

associated policy issues.[6] The output is a comparative analysis of approaches and assignments across multiple dimensions: frequency bands, Member States, sectors, and technologies. We also reviewed the status of policy and technology developments worldwide, and assessed their potential for improving the efficiency of public sector spectrum use and the opportunities for sharing with commercial services.

We relied on a number of spectrum allocation databases. EFIS[7] (ERO Frequency Information System) is the European database of spectrum allocations. It provides details on the allocations and applications for all users of radio spectrum in CEPT countries. It should be noted that some countries currently provide only limited information to EFIS; where possible, we have therefore supplemented our data with information from national frequency allocation tables, or by contacting NRAs, or from other sources as appropriate.

In addition to the desk research, we interviewed key stakeholders in public sector spectrum use and management. We conducted approximately 40 face-to-face and telephone interviews with spectrum management authorities, international organisations, and representatives of the three sectors we have been asked to study: defence, transport, and emergency services.

We have also liaised with the *Public Use of Spectrum (PUS)* Working Group, an activity that the *Radio Spectrum Policy Group (RSPG)* has launched at the request of the European Commission.[8] We appreciate the fruitful interchange of views and information with the PUS and its members. We have exchanged data with the PUS Working Group, to the extent that our respective charters and obligations permit.

1.5 Organisation of this report

This Introduction represents Chapter 1 of the Draft Final Report. Chapter 2 briefly reviews current arrangements at a sectoral level. (The separate Annex to this report provides considerable supporting detail.) Chapter 3 discusses opportunities for new technology to improve the efficiency of public sector spectrum use, while Chapter 4 describes opportunities for policy changes to improve the efficiency of public sector spectrum use going forward. Chapter 5 provides our findings and recommendations.

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6 Martin Cave, et al, "Is public sector spectrum management different?", in *Essentials of Modern Spectrum* (Cambridge University Press 2007).

7 Available at http://www.efis.dk

8 See http://rspg.ec.europa.eu/doc/documents/meeting/rspg14/rspg07_188_req_op_publicsector.pdf

2 Current situation

This Chapter of the report briefly describes the current situation of spectrum management in the public sector, in terms of the relative magnitude of spectrum use by defence, public safety, and various forms of transport. In order to keep the report manageable and readable, much detail has been abstracted to the Annex that accompanies this report.

Section 2.1 describes public spectrum allocations and uses as they exist today. (Administrative institutional arrangements are discussed later in Section 4.3.1, and at greater length in the separate Annex to this report.) Section 2.2 provides an overview of spectrum use by the defence, emergency services, and aeronautical and maritime transport sectors, respectively. Section 2.3 reviews relevant spectrum management enhancement initiatives that are already under way. Section 2.4 summarises the key elements and findings of the chapter.

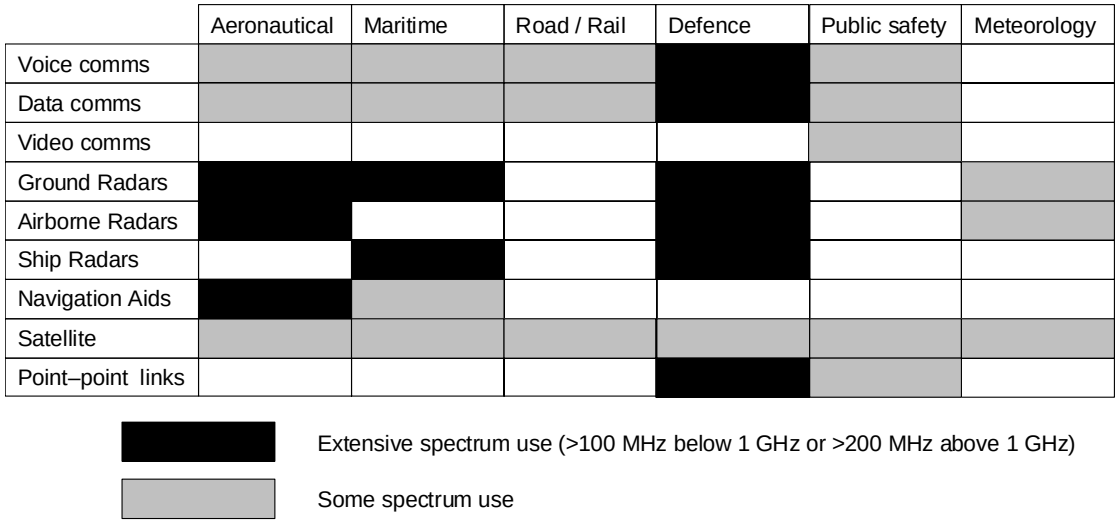
2.1 Public sector spectrum allocations

This section presents an overview of spectrum currently allocated for public sector use in Europe and is intended to give a sense of the relative magnitude of different kinds of public sector use. More detailed information, including country-by-country comparisons of frequency use, appears in the Annex that accompanies this report. Information on spectrum allocations has been sourced primarily from the EFIS[9] (ERO Frequency Information System) database of European spectrum allocations (which is described in Section 4.2.1), supplemented where necessary with information from national administrations and sector-specific international bodies responsible for spectrum planning.

The public sector uses spectrum in many ways, from straightforward voice or data communication to specialised applications like weather radars and radio altimeters. Spectrum can be categorised either by user sector or by application, as illustrated by the matrix in Figure 1.

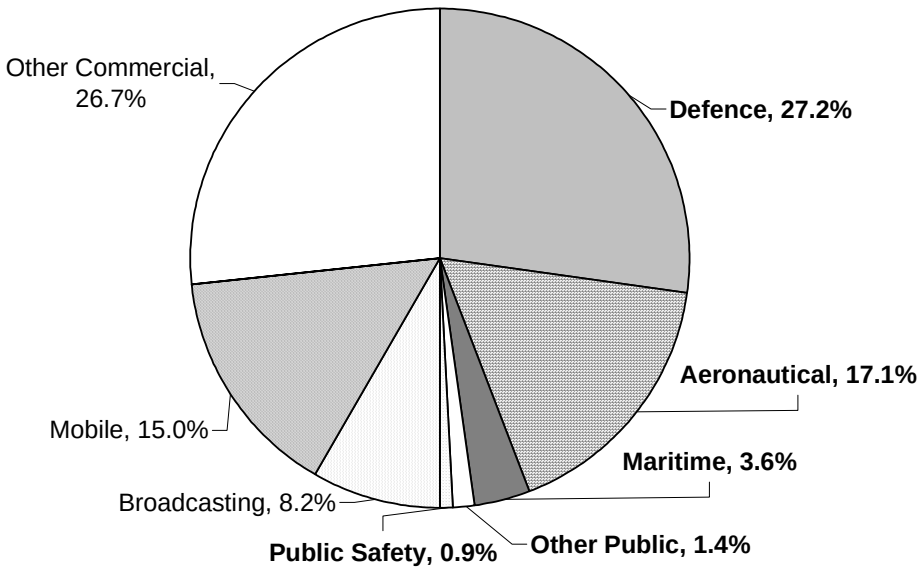
9 Available at http://www.efis.dk

Figure 1: Public sector spectrum use by application and sector



About half of the allocated spectrum between 108 MHz and 6 GHz (the spectrum that is most sought after for commercial applications) has the public sector as primary user. The three largest public sector users in bandwidth terms are the defence, aeronautical and maritime transport sectors, as illustrated in Figure 2.

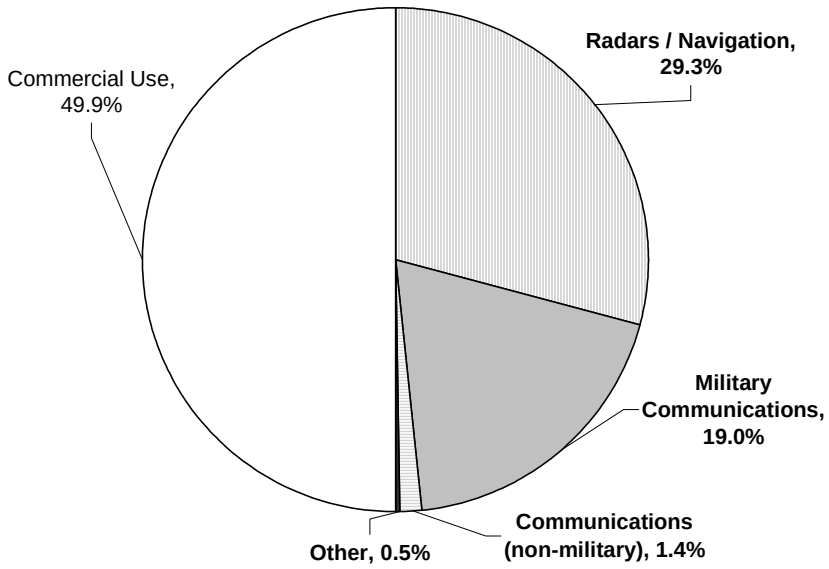
Figure 2: Spectrum allocations by sector (108 MHz – 6 GHz) in a typical EU country[10]



Broadly speaking, spectrum use can be split into two distinct categories, namely communications (voice, data or video) and navigation / location systems (radar, beacons, satellite navigation). Communication systems generally operate in bands below 3 GHz, with the exception of point-to-point and satellite backhaul links, whereas navigation / location systems operate throughout the spectrum, from the very low frequency (VLF) to the microwave and millimetre-wave bands. The proportion of spectrum between 108 MHz and 6 GHz used by various applications is illustrated in Figure 3.

10 The figures include the main harmonised allocations plus national assignments applicable to the UK. Harmonised allocations account for over 90% of public sector spectrum allocations (in bandwidth terms). Note that to avoid double counting we have assumed that all spectrum used by the civil aviation and maritime sectors is classed under those sectors, even where this spectrum is also used by the Defence sector. Where spectrum is widely used for commercial applications but is also used by the Defence sector (e.g. the 5 GHz WLAN bands), this has been classified as commercial.

Figure 3: Spectrum allocations by application (108 MHz to 6 GHz)



It is clear from Figure 3 that the most significant public sector uses of spectrum are radar / navigation systems and military communications. Although aeronautical and maritime communication is a vital application for those sectors, most of this communication is relatively narrow band and the overall spectrum requirement is relatively modest. It should also be noted that there is considerable sharing between civil and military users in the public sector, particularly for aeronautical and maritime applications. In many countries, spectrum that is managed by the military is shared with commercial uses, typically on a geographic or time limited basis. Whilst these constraints would not generally be appropriate for commercial wireless services, more specialist use such as PMSE (programme making and special events) can be accommodated. The military also makes use of some spectrum that is primarily used by the commercial sector, such as the 2.4 GHz and 5 GHz bands that are used by WiFi and other wireless access systems.

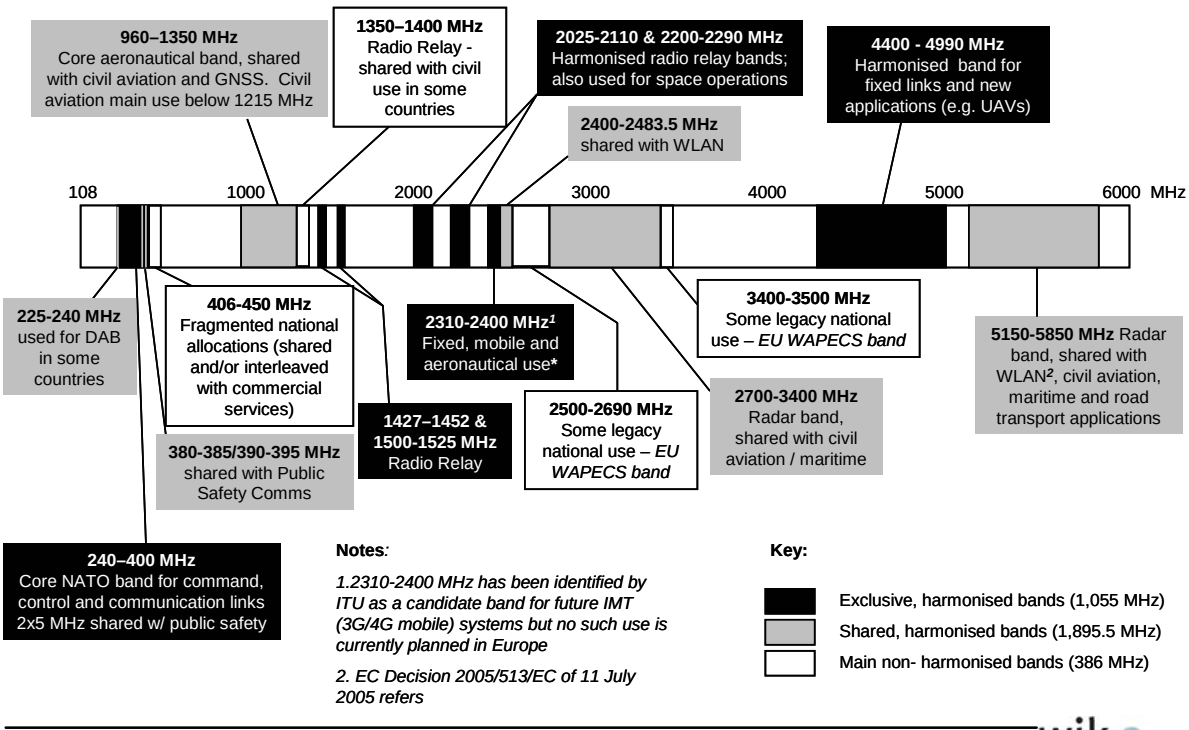
Much of the spectrum allocated to public sector use is by necessity harmonised internationally. This applies particularly to aeronautical spectrum, where both the safety-critical nature of the application itself and the very large distances travelled by airborne radio signals make a strong case for harmonised use across the globe. Similar arguments apply to maritime spectrum.

Military spectrum allocations are often the result of regional or multilateral agreements emanating from bodies such as the North Atlantic Treaty Organisation (NATO) or the former Warsaw Pact, although a number of country-specific allocations have emerged over the years. This legacy means there are significant variations in spectrum that has historically allocated to the military in different parts of Europe and a transition is necessary in some cases. This can lead to interference problems where the legacy use coincides with new internationally harmonised bands, particularly where these are used for licence-exempt applications. In other cases legacy military use can be a constraint on introducing new licenced services, for example some countries still have military systems operating in bands that are important for future wireless communication systems, such as 2.6 GHz and 3.5 GHz.

Stakeholder feedback indicates that legacy military allocations of spectrum are declining in relevance over time. Former Warsaw Pact members have moved quickly to decommission old equipment and replace it with gear that conforms to NATO allocation plans. Country-specific allocations that do not conform to NATO allocation plans are also becoming increasingly rare.

The diagram below illustrates the main bands used by the defence sector in Europe and the extent of sharing within these bands:

Figure 4: Main defence frequency bands in Europe



2.2 Defence, emergency services, and aeronautical and maritime transport in Europe

This section of the report briefly reviews key characteristics of spectrum use in the defence (Section 2.2.1), emergency services (Section 2.2.2), aeronautical transport (Section 2.2.3), and maritime transport sectors (Section 2.2.4), respectively.

2.2.1 Defence

Defence poses many challenges to improvements in the economic efficiency of spectrum allocation and usage. In defence, as in a number of sectors, spectrum management is partly managed at the national level and in part coordinated internationally. NATO and the European Defence Agency play particularly prominent roles in international coordination. International interoperability in terms of defence is vital for European Member States. NATO imposes harmonisation at international level (membership includes most but not all EU Member States as well as several non-European countries), while EDA operates at European Union level.

The scope at national level to release unneeded spectrum is constrained in some bands, particularly those which are NATO-managed or harmonised.

Historically, a number of (newer) Member States were parties to the Warsaw Pact, and thus historically adhered to a different and incompatible set of defence spectrum allocations. These historical allocations are rapidly being phased out as these Member States integrate with the rest of the European Union.

Much equipment has a long life cycle, which implies that improvements will tend to be slow to deploy.

Many radio systems in this sector are designed to operate in hostile electromagnetic environments. Systems designed for hostile environments should be inherently suitable for sharing spectrum with other users; however, certain applications, particularly those relating to airborne systems or those providing vital communications between field forces and central command, require a high degree of protection, which may imply a need for exclusive spectrum assignments.

2.2.2 Emergency services

Emergency services do not use large volumes of spectrum, but their usage is of vital importance to society.

Emergency services networks can be national or regional, and address the needs of the many different users, including:

- Police
- Firemen
- Ambulances
- Public safety
- Prisons

The emergency services sector tends to be highly fragmented. Many small organisations operate at the local level, often with limited funding. This has implications for the speed with which enhancements could be introduced, inasmuch as there may at present be no good funding vehicle for equipment upgrades.

This fragmentation also potentially complicates a coordinated response when a natural disaster or terrorist incident crosses national borders. There is an increasing recognition in the sector of the need for highly interoperable solutions. Thus, the desire for higher speed data transfer, and for video, in conjunction with these growing needs for cross-border interoperability is driving an increasing demand for broadband capabilities for emergency services that are interoperable at the European level.

To be sure, the emergency services sector has already made good progress towards adoption of digital standards for voice and for narrowband data services. Most EU countries have at least partly migrated their emergency service communications to digital trunked mobile networks (either TETRA or Tetrapol) operating in the harmonised 380 – 400 MHz band.

Emergency services make some use of standard commercial systems; however, the need for emergency services to operate even in the midst of a disaster limits the use of commercial systems, which in most cases are not designed for that level of reliability and robustness.

Opportunities to share spectrum with the private sector are being explored, notably in the United States. Commercial users would need to vacate the band immediately in the event of an emergency. Technical means of enforcing the necessary pre-emption are a real possibility with current technology.

An alternative that has not been fully explored to date is the possibility of sharing spectrum with the military. Emergency services and defence have similar needs for reliability and robustness, and they might need to work together in any case in certain kinds of emergencies.

2.2.3 The aeronautical sector

The aeronautical sector is by its very nature global; consequently, sectoral arrangements often play a more significant role than national arrangements. Much of our discussion of this sector focuses on international arrangements in consequence.

Adoption of new radio technology in the aeronautical sector has primarily been driven by the need to increase capacity in response to the massive growth in commercial air traffic, and secondarily by the desire to reduce cost (e.g. by reducing the size and weight of equipment carried on board aircraft and hence reducing fuel consumption). The need to increase capacity in some bands (e.g. the aeronautical VHF communications band) has led to significant improvements in spectrum efficiency; however, in other cases where there have been no capacity constraints (e.g. primary radar bands) there has been little or no improvement over time.

There are long term plans to introduce digital technology for aeronautical communications, but this requires re-planning of the current international Air Traffic Control arrangements and the cooperation of all the airlines. Efforts to date have therefore concentrated on improving the efficiency of existing analogue communication systems by progressively reducing the required channel bandwidth. The latest reduction from 25 kHz to 8.33 kHz applies to the higher flight altitudes used by commercial airliners and should enable future traffic growth to be accommodated for the next decade or so, but a more radical solution is required for the longer term. This is being addressed in a joint study by the US FAA and Eurocontrol that seeks to develop the next generation of airborne communications.

2.2.4 The maritime sector

Communications are essential in the maritime transport sector, both for routine operations and for safety purposes. They serve professional seafarers and leisure craft.

The bulk of maritime spectrum is harmonised (2900 - 3100 MHz and 5470 - 5650 MHz). Also, some bands used for maritime applications are shared with other applications concluded between representatives of the maritime and of the defence sectors; agreement defines the geographical sharing of spectrum.

Sharing inland is already in place for maritime radars in the 2900 – 3100 GHz band shared between maritime and military radars applications. However, only the bands used for ship-based operations are concerned by international rules. Assignments for shore based services are carried out on a national basis.

The maritime sector, like the aeronautical sector, is by its nature global; again, sectoral arrangements play a significant role, although there is also substantial scope for national arrangements.

2.3 National initiatives in spectrum management for the public sector

In recent years, a number of countries have conducted significant national policy reviews concerning public sector spectrum management and use: Australia (2008), the Netherlands (2005), Sweden (2007), the UK (2005), and the US (2008). Further details on these initiatives are available in the Annex to this report. In all cases, the purpose of the review was to identify ways of improving the efficiency and effectiveness of public sector spectrum use. As the reviews are very recent implementation of the review recommendations has only just started in the Netherlands and the UK.

In most cases, the reviews have undertaken an examination of the use of public sector bands. This provides the information base for any assessment of efficiency of use, and helps the public sector user to identify candidate opportunities for sharing or otherwise releasing spectrum where exclusive use is no longer required. Next, specific bands where spectrum might be released or shared are evaluated in greater detail, which often requires additional studies to be undertaken to ensure that any changes do not result in harmful interference or otherwise reduce safety or security requirements. In all cases, opportunities for spectrum release or additional sharing have been found.

The reviews have examined the extent to which administrative arrangements for managing public sector spectrum could be improved variously through (1) the application of more formal licensing arrangements, (2) collecting and disseminating more information on use, (3) the application of IT in licensing and co-ordination activities, and (4) better integration with the management of non-public sector spectrum. Finally, in some cases the potential for use of market-inspired[11] approaches to spectrum management such as pricing, trading and auctions has been considered.

Table 1 contains a summary of the main recommendations from the reviews. Follow-up actions are also noted. While reviews in each country place different degrees of emphasis on specific policy reforms, there are common elements, including:

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11 In this report, we generally refer to these mechanisms as *market-inspired* rather than *market-based*. The use of Administrative Incentive Pricing (AIP) is market-inspired, but it is not market-based (because the price has not been set by the market); spectrum trading, however, could be said to be both market-inspired and market-based.

- Audits of current use and forecasts of future requirements;
- Approaches to increase the technical efficiency of use and thereby accommodate more intensive use of the bands in question through sharing or release to other uses;
- Changing administrative arrangements that impact on spectrum demand and use – licensing of public sector users, use of IT to reduce costs and allow more intensive spectrum use, changing procurement processes so users' spectrum requirements become a factor in the choice of systems. Greater transparency in the rights of public sector users enables the co-ordination required to share and/or use neighbouring bands more intensively. In the UK, the Ministry of Defence has proposed use of a third party band manager to manage its interactions with the market and to undertake day to day management of its exclusive allocations and possibly of its shared allocations.
- Possible use of market-inspired approaches to providing public sector users with financial incentives for economically efficient spectrum use. The application of such approaches has however been limited so far. The use of market-inspired mechanisms depends on clear definition of the access rights of public sector users. In some countries, access rights are not sufficiently well defined at present.

Table 1: Summary of Recommendations and Actions from National Initiatives

Type of recommendation	Country details	Actions
Spectrum audits	Netherlands - Conduct three yearly audits of public sector spectrum use – Netherlands UK - Detailed audit of Ministry of Defence bands required Australia - Increase transparency in use of spectrum by the public sector (use regular audits) esp. Defence	Netherlands: First audit completed. Second audit to start in 2008. Some spectrum returned and sharing opportunities found UK: Audit of Ministry of Defence bands on-going. Bands for sharing/release identified. US: NTIA has just completed a comprehensive audit of usage by Federal agencies.
Forecast future spectrum requirements	UK - Public sector to produce a forecast of requirements every two years – the "Forward Look" Australia – Form a committee to advise on future government priorities Netherlands – produce forecasts as part of 3 yearly audits US - Do further work to quantify future spectrum requirements	UK - First "Forward Look" published

Type of recommendation	Country details	Actions
Improve technical efficiency	Sweden - Defence to adopt new digital equipment to facilitate sharing/spectrum release US - Investigate sharing using dynamic frequency systems	UK - Study to rationalise aero navigation aids started
Release spectrum for other users – sharing or release of bands for others	UK - Seek to release spectrum in particular bands Australia – increase sharing in public sector bands. Incentivise through licence fee relief Sweden - Re-plan and increase sharing in Defence bands US – Use more dynamic spectrum technologies to share public sector spectrum allocations.	UK - Radar sharing trials commence; A Ministry of Defence consultation document published setting out plans for spectrum release[12]
Automated coordination between sectors	US - Automate spectrum co-ordination and sharing among federal users and between the NTIA and FCC by means of IT	
Licensing	UK - Formalise public sector spectrum access through a legal instrument termed Recognised Spectrum Access[13] Australia – put public sector licensing on same basis as for commercial use; develop criteria for renewal of public sector licences	Policy statement on imple-menting a tradable Recognised Spectrum Access (RSA), subject to Administered Incentive Pricing (AIP)
Procurement	Australia – early identification of spectrum requirements for major public sector projects US - Integrate spectrum value in capital budgeting for new spectrum-dependent systems	
Market approaches	UK - Adopt market mechanisms (pricing, trading and auctions) US – Interest, but no specific actions Australia – continue to apply market approaches where practicable; allow public sector users to make financial gains from improved spectrum use Netherlands – rejected use of spectrum pricing Sweden - Consider application of pricing	UK - Extension of AIP to more bands (esp. MoD) Study on applying AIP to aero/maritime bands US - Refarming of public sector spectrum using auction proceeds

12 406.1-430 MHz and 3400-3600 MHz are to be released in 2008-2009 and eight possible bands between 4.4 GHz and 15.2 GHz in 2009/10 have been identified.

13 In the UK many public sector organisations do not need to be authorised (by law) to use spectrum.

In respect of applying market approaches to public sector spectrum use, Australia has allowed trading of public sector spectrum for some time, but there has been relatively little activity. It is thought that this is partly because public sector organisations are less likely to respond to a theoretical opportunity cost (the value were the spectrum traded) than an actual cost.

It is for this reason that the UK regulator has applied spectrum pricing to incentivise more efficient spectrum use by public sector organisations and why this policy is being used in Canada and considered in Australia, Sweden and the US. The Netherlands rejected spectrum pricing for public agencies because of the difficulties in calculating a robust set of spectrum prices. Such prices have been set in the UK, albeit with a deliberate bias on the low side because of the uncertainties involved.

The UK experience suggests that implementation of a full range of market-inspired mechanisms for management of public sector spectrum requires careful planning and management, and that is cannot be done overnight. Their approach depends not only on setting prices (AIP) for spectrum use, but also on changes to the budgeting process to ensure that public sector entities benefit from savings and trades. Spectrum rights must be clearly defined, and as flexible as possible, if they are to be tradable. The UK has made great strides, but there is still much work to do.

2.4 Summary

The public sector is a significant user of radio spectrum. The public sector uses this spectrum to achieve a multitude of absolutely vital functions to their inhabitants, including national security; fire, police, emergency medical services; and safety and navigation on the ground, on water and in the air.

The most significant public sector uses of spectrum are radar / navigation systems and military communications. Although aeronautical and maritime communication is a vital application for those sectors, most of this communication is relatively narrow band and the overall spectrum requirement is relatively modest.

A number of countries (in Europe and around the globe) have undertaken reviews of spectrum management for the public sector in recent years, including Australia (2008), the Netherlands (2005), Sweden (2007), the UK (2005), and the US (2008). All have sought to enhance the effectiveness and efficiency of the spectrum management process, and all have evaluated the possible applicability of market-inspired mechanisms to the public sector.

The reviews in the UK and the Netherlands are particularly relevant to this report, for two reasons. First, both reflect well thought out approaches to the task, and both are far enough along that one can draw at least preliminary conclusions about the

effectiveness of what has been implemented. Second, they have taken significantly different approaches, with the Netherlands placing primary reliance on administrative mechanisms, and the UK placing primary reliance on market-inspired mechanisms. A key lesson from the UK is that effective implementation of the market-inspired approach depends on the implementation of a range of administrative reforms.

3 Technological opportunities to improve the use of spectrum by the public sector

Radio technology has advanced enormously since the first wireless services appeared, providing both performance improvements and a massive increase in the capacity of the available spectrum. The public sector has taken advantage of many of these developments, but the pace of change has by necessity been slower than in some parts of the commercial sector. This reflects the very demanding operational parameters that apply to many public sector applications, particularly in the aeronautical and defence sectors, and the global nature of many users. For example, deployment of a new wireless system relating to flight safety can require several years of development and testing to prove its capability, and its deployment may require costly and time-consuming upgrades to the in-flight equipment on hundreds of thousands of planes. On the other hand, the benefits in terms of operational efficiency, safety and long term running costs can also be significant, and in some cases technology evolution is essential to accommodate growth in the sector; thus, ongoing evolution is often warranted and cost-effective, even if the process is sometimes slower and more costly than in the commercial sector.

Section 3.1 provides general background on the use of technology within the public sector. Section 3.2 discusses opportunities to share spectrum between public sector users and either private sector or other public sector users. Section 3.3 discusses specific opportunities to improve the efficiency of radar, which is a heavy user of spectrum. Section 3.4 summarises the points raised in this chapter. The separate Annex to this report provides extensive supporting detail as to use of spectrum in the public sector.

3.1 Technology evolution in the public sector

Adoption of new radio technology in the public sector has largely been driven by the need to increase capacity (particularly the case with aviation where there has been massive growth in commercial air traffic), to improve operational effectiveness (e.g. by providing greater interoperability between users), and in some cases to reduce cost (e.g. by reducing the size and weight of equipment carried on board aircraft and hence reducing fuel consumption). The need to increase capacity in some bands (e.g. the aeronautical VHF communications band) has led to significant improvements in spectrum efficiency; however, in other cases where there have been no capacity constraints (e.g. primary radar bands) there has been little or no improvement over time.

The greatest improvements have been achieved in communication systems, which have been subject to the greatest growth in demand and have also been able to benefit

from parallel developments in other sectors, such as the migration to digital transmission. Radars and navigation aids have more limited scope to improve spectrum efficiency, since the required bandwidth is largely a function of the operational requirements (e.g. range or target resolution). The extreme sensitivity of many radar receivers also limits the scope for sharing with other types of radio system.[14] Nonetheless, the increasing adoption of solid state technology in place of vacuum tubes has brought some improvement, particularly with regard to out-of-band emissions, and has created scope for more radars to be accommodated in a given amount of spectrum (thus potentially freeing up spectrum for other applications).

In the defence sector, many radio systems are designed to operate in hostile electromagnetic environments. Systems designed for hostile environments should be inherently suitable for sharing spectrum with other users; however, certain applications, particularly those relating to airborne systems or those providing vital communications between field forces and central command, do require a high degree of protection, which may imply a need for exclusive spectrum assignments. There may be scope for greater sharing with defence, but careful study would be required.[15]

One sector which has made good progress towards adoption of digital standards is public safety, where most EU countries have at least partly migrated their emergency service communications to digital trunked mobile networks operating in the harmonised 380 – 400 MHz band.

There are long term plans to introduce digital technology for aeronautical communications as well, but this requires re-planning of the current international Air Traffic Control arrangements and the cooperation of all the airlines. Efforts to date have therefore concentrated on improving the efficiency of existing analogue communication systems by progressively reducing the required channel bandwidth. The latest reduction from 25 kHz to 8.33 kHz applies to the higher flight altitudes used by commercial airliners and should enable future traffic growth to be accommodated for the next decade or so, but a more radical solution is required for the longer term. This is being addressed in a joint study by the US FAA and Eurocontrol that seeks to develop the next generation of airborne communications (see box below).

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14 It is, however, common for radars to share bands with one another through careful planning. In fact, the degree of sharing between military and civilian radars is noteworthy.

15 In France, roughly two-thirds of all defence spectrum is shared, much of it with other public sector spectrum users. It is difficult today to determine the effectiveness of sharing in the EU for reasons noted elsewhere (see Section 4.2.1).

Future Aeronautical Communication Systems

Aeronautical communications currently is predominantly voice based, but demand for data communications is growing and will lead to increasing spectrum demand in the future. A number of studies are under way into how the latest digital multi-carrier technologies could be deployed in the aeronautical sector to accommodate this longer term growth. For example, the US Federal Aviation Authority (FAA) and Eurocontrol are undertaking a bilateral study on future communications systems (FCS), and ICAO is seeking a common, global solution through its Aeronautical Communications Panel (ACP).

The FCS study is seeking to identify technologies suitable for a new Global Aeronautical Communication System that could be deployed in the 2015-2020 timeframe. This would alleviate congestion in the aeronautical bands, and would also avoid the current requirement for multiple systems to be carried by aircraft to support different technologies in different parts of the world (thus reducing operators' costs in the long run). The study has identified a wide range of technologies, and has emphasised the following as having the most promise for future communications systems[16]:

- Remote / Long Range: satellite (Inmarsat Swift Broadband and possible custom solutions)
- Continental / Medium Range: W-CDMA, Enhanced TDMA, L-band data link (LDL), Broadband VHF up-banded to L-band
- Airport / Short Range: IEEE802.16e in the 5091-5150 MHz band.

The results from the FCS study will be an important input to the European Commission funded SESAR (Single European Sky Air Traffic Management Research) programme, which is intended to improve the capacity, safety and efficiency of air traffic management (ATM) in Europe. The objectives include (1) a three-fold increase in capacity, (2) a ten-fold improvement in safety, and (3) operating costs lower than those of today's ATM systems.

The definition phase concluded in 2007. The implementation phase is now under way, with the objective of completing development by 2013 and achieving full implementation by 2020.

Another study undertaken for Eurocontrol indicated that the spectrum requirement for medium range voice and data communications for commercial air traffic in the European air traffic control area using the FCS approach would be in the range 16 -

16 See "Future Communications Study Overview", input to Air Ground Communications Focus Group and NexSAT Steering Group, Sept 18, 2006, by Brent Phillips (FAA) and Jacky Pouzet (Eurocontrol).

22 MHz, or 10 - 20 MHz if video services are not required. The current preference is to locate the new system in the 960 – 1178 MHz radio navigation band (L-band); however, there are concerns about whether this would be compatible with existing systems (notably DME, which already has a limited interference margin owing to the need to share spectrum with the military JTIDS system). There are no current plans to migrate from existing analogue VHF voice communications to the new system; rather, the two will be complementary, which appears to run counter to the desire to reduce the number of systems aircraft are required to carry. There are also no current plans to accommodate digital communications in the VHF band, although the phasing out of VOR systems in the VHF radio navigation band would allow scope for this.

Note that the FCS study is not addressing the longer term need for very large bandwidths to support airborne telemetry requirements, which some have suggested could require access to hundreds of MHz of spectrum[17]. This is largely related to deployment of unmanned aeronautical vehicles and for in-flight testing, and some additional spectrum was identified for such applications at the 2007 World Radio Conference. We believe there is scope to accommodate further requirements, which we would expect to be accommodated in existing military spectrum (for example in the 4400 – 4990 MHz range) building on existing civil-military sharing arrangements in the aeronautical field.

3.2 Opportunities for greater sharing between services

Sharing of radio spectrum (i.e. the use of the same frequencies by more than one entity) is one way of addressing growing spectrum demand. Sharing is already practised to some extent by public sector users. Historically, *static sharing* of spectrum between different users has relied on prior arrangements where the sharers would use the spectrum at different times, or would apply a fixed geographic or frequency separation to avoid interference. Because radio propagation conditions vary with time, and given that the required separation is typically based on near-worst case scenarios, this static sharing can result in a significant proportion of spectrum being unusable at any given location. This unusable spectrum is sometimes referred to as the "white spaces" between the active spectrum assignments.

Some uses of spectrum, both in the public and in the commercial sectors, only require access on an occasional basis and are ideal candidates for sharing on a *dynamic* time-coordinated basis. This approach is considered in Section 3.2.1 below.

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17 According to ITU WP 8B document 143 "Spectrum Requirements for Airborne Telemetry" submitted by US Administration, airborne telemetry for test aircraft will require bit rates of 100s of Mbps and spectrum of 500 MHz or more in the longer term.

In recent years, a number of technologies have been proposed to enable these white spaces to be dynamically put to use without compromising the operations of the existing spectrum users. Some of these techniques are considered in Section 3.2.2. We return to the policy implications of dynamic spectrum sharing in Section 4.4.

3.2.1 Sharing between occasional spectrum users

We see many opportunities to share spectrum with the public sector, either statically (by prior arrangement) or dynamically (by automatic adjustment to circumstances in the band, possibly involving pre-emption).

As explained in Section 3.2, the nature of certain public sector agencies' operations means that the "average" or long-term spectrum requirement can be very different from the peak requirement that is likely to arise during major incidents (for public safety) or training exercises (for defence). Hence, there is likely to be benefit in a combination of dedicated and shared use spectrum, where the shared use spectrum is utilised dynamically to address peaks as and when they arise. Shared use could be on a pre-emptive basis, where the spectrum is cleared for public safety use during emergency situations (sometimes referred to as callable or interruptible spectrum). For example, commercial operators could use the spectrum in the presence of a pilot tone, but when the tone is gone, must vacate to allow use by the public sector user (see for example the discussion of ITU's "cognition-supporting pilot channel" (CSPC) in Section 3.2.2). This should provide an essentially fail-safe system. We return to these dynamic approaches in Section 3.2.2.

There is also the possibility to share spectrum on a static, temporal basis. Whilst it is important to ensure that access to spectrum be guaranteed to the public sector user, the possibility exists to use the spectrum for Temporary Commercial Use, which is to say that spectrum can be used for other applications when it is not needed by the primary user. One noteworthy example of Temporary Commercial Use is *Programme Making and Special Events (PMSE*), particularly where spectrum is required for major events that can be planned well in advance.

PMSE services have a long history of sharing with the military; however, there is evidence to suggest that even wider sharing with the public sector is feasible. For example, work undertaken by CEPT[18] has indicated that geographic sharing between S-band primary radars and PMSE applications such as wireless cameras is feasible at separation distances as low as 3 km. Greater access to public sector spectrum for PMSE applications could be particularly beneficial, given that many of the bands traditionally used by PMSE services have been re-allocated to other commercial users

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for whom sharing is not a realistic proposition. The growing demand for high definition wireless cameras also drives demand for spectrum for PMSE.

Another potentially attractive time-based sharing scenario is between military and public safety users. This would be attractive on at least two counts, namely:

- Commonality of purpose: Both military and public safety organisations have an active interest in national security. There would likely be benefits to both from greater interoperability between radio systems, in much the same way that the individual public safety organisations (such as police, fire, and ambulance) have benefited from adoption of integrated, digital networks. They also have similar requirements for reliability of communications.

- Potential for coordinated access: As already noted, much military spectrum is used only episodically (e.g. for training exercises). It should be feasible to arrange for such spectrum to be available to public safety organisations on short notice when needed to address major incidents. Military authorities are likely to be in a better position to respond to such urgent situations than commercial spectrum users, and less likely to suffer disruption as a consequence.

3.2.2 Technologies to support sharing between spectrum users

Technologies exist and are evolving further to support continuous access to spectrum on a shared, dynamic basis – the "white space" spectrum identified earlier in 3.1.2 for example. These dynamic spectrum usage techniques could also simplify technological evolution over time, inasmuch as it might no longer be necessary (in some cases, at least) to deploy new equipment as requirements change over time. Dynamic techniques could potentially simplify the coexistence of old equipment with new, and might also be useful for band-clearing where a band has been refarmed.

Probably the most significant development in this area is *Cognitive Radio*, which combines existing techniques such as *Dynamic Frequency Selection (DFS)* with newer concepts such as *Incumbent Profile Detection (IPD)* to provide a more adaptive and intelligence-based approach to spectrum sharing. IPD refers to the ability of a radio system to identify the nature of an incumbent's signal by analysing its key technical characteristics, and adjusting its own transmissions to ensure that interference is avoided. In effect, this adds a degree of "intelligence" to the DFS function, which essentially only detects that a signal is present above a certain threshold.

The experience of DFS

DFS has been deployed for several years in the 5 GHz wireless local area network (WLAN) bands to facilitate coexistence with incumbent radar systems (mainly military and meteorological) on which no other signals are detected. To be effective, DFS requires the WLAN receiver to be able to detect any radar transmission that may be present in the band. The standard originally developed (EN 301 893) was based on detection of most known types or radar emission in the band at that time. Because of a few reported instances of interference into certain types of weather radar in Europe and other parts of the world, the standard has since had to be modified to accommodate new types of radar with very short pulse durations (less than 1 μsec) and variable pulse repetition frequencies (PRFs).

The experience of DFS at 5 GHz has confirmed the feasibility of sharing between radars and low power communication systems, but has also shown that continuing technological effort has to be made in order to ensure sharing opportunities are successfully exploited as technologies evolve over time.

Another technology that can also assist sharing and that is often combined with Cognitive Radio is Software Defined Radio (SDR). With SDR, parameters such as frequency range, modulation type, or output power can be set or altered by software, with the changes either implemented locally (possibly manually), or else downloaded automatically over the air interface. For the military, SDR is seen as a way to provide greater flexibility to respond to local operating conditions and to provide greater interoperability with other systems, including civil communication networks.

SDR potentially simplifies the evolution of public spectrum-based services over time, inasmuch as equipment could be dynamically reprogrammed as needed.

SDR potentially has wide applicability in the public sector. One example of SDR that is already in development is NATO's Joint Tactical Radio System (JTRS), which is intended to enable personnel to communicate with a wide variety of new and existing communications systems, as well as help older radios interoperate with one another. Field JTRS radios can be upgraded with new software via the air interface. This technique provides frequency agile operation over the range 2 MHz to 2 GHz, and includes wideband capabilities for video and data communication. The new equipment has the potential to replace a range of separate legacy radio systems, many of which operate in country specific bands.

By combining the attributes of DFS, IPD and SDR, a Cognitive Radio system is able to detect and identify incumbent users on a particular frequency and to reconfigure its own transmissions. By reconfiguring itself to use a different frequency from that used by the

incumbent, or by changing other transmission parameters (e.g. transmit power), the CR can avoid causing interference to the incumbent, and can also avoid the risk of itself suffering harmful interference from the incumbent.

Standards development is under way for both CR and SDR. CR is currently under study within the ITU and IEEE standards fora, with a view to establishing whether there is a need for any specific regulatory measures.[19],[20]

At the same time, we would note that CR should not be viewed as a panacea (cure-all), and that further research is needed. One of the concerns that has often been raised about CR is the potential failure of the CR receiver to detect a transmission, which could lead the CR to transmit and thus to subsequently cause interference to the incumbent user. This could arise where the cognitive radio is shielded from the incumbent's transmitter but not from the incumbent's receiver – sometimes referred to as the "hidden node" problem.

One solution that is being considered by the ITU is the use of a *cognition-supporting pilot channel (CSPC)* operating on a fixed global frequency or on a limited set of regional frequencies. The channel would provide information on the appropriate frequency and/or technology that the cognitive / software defined radio should use at a particular location. In the absence of a pilot signal, no transmission would take place. Another approach would be to use a geographic database of frequencies; however, this would require the transmitting device to be location aware, which may not always be practical. Trials of Cognitive Radio to facilitate sharing of the TV broadcast band with other services have been undertaken by the FCC, but so far have had limited success.[21] These technologies will continue to be refined going forward.

The United States FCC attempted a form of sharing between emergency services and private sector users, where public safety users would be able to pre-empt private sector users in a portion of the 700 MHz band when needed. Had it been implemented, this scheme would have presumably depended on some CR approach to pre-emption. The FCC sought to "… form a Public Safety/Private Partnership to develop a shared, nationwide interoperable network for both commercial and public safety users. … The public safety broadband network will facilitate effective communications among first responders not just in emergencies, but as part of cooperative communications plans that will enable first responders from different disciplines, such as police and fire departments, and jurisdictions to work together in emergency preparedness and response. …Under the Partnership, [public safety entities] will have priority access to

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19 Cognitive and Software Defined Radio are addressed under Agenda item 1.19 of the 2011 World Radio Conference (WRC-11).

20 See for example "Cognitive Radio Emerges from Obscurity", presentation by John Notor of Cadence Design Systems, January 23, 2004.

21 See for example, "Initial evaluation of the performance of prototype TV-band white space devices", FCC OET report 07-TR-1006.

the commercial spectrum in times of emergency, and the commercial licensee will have preemptible, secondary access to the public safety broadband spectrum. Providing for shared infrastructure will help achieve significant cost efficiencies while maximizing public safety's access to interoperable broadband spectrum."[22]

This approach would appear to be sound in principle, but it has not yet been successfully launched. The auction of the spectrum band did not generate bids that reached the FCC's reservation price. It is premature, however, to say that the approach has failed; one alternative interpretation is that the FCC simply set too high a reservation price. The risk that the spectrum could be pre-empted may lower its value more than the FCC assumed. It is important to bear in mind that the primary function of an auction is to ensure that spectrum gets into the hands of those who value it most; raising money for the government is at most a secondary benefit, and has many of the same economic implications as other forms of taxation (which is to say that the revenue is by no means "free"). Thus, it is possible that the FCC's approach could still work with minor fine tuning and a lower reservation price.

3.3 Improvements in radar technology

As we saw in Figure 3, radars and navigation systems represent the greatest use of spectrum by the public sector. There are many different types of radar system, from simple handheld radars used by the Police to detect speeding motorists to large complex systems designed to detect airborne targets at distances of hundreds of km. Aeronautical and maritime surveillance radars play an important role in maintaining safe operation of these sectors by providing accurate information on the location and velocity of aircraft, ships and potential hazards. To perform this function effectively, the radars must operate over a sufficient range and must provide sufficient resolution between two nearby objects so as to minimise the risk of collision.

L-band (960 – 1350 MHz) and S-band (2700 – 3400 MHz) are attractive for radar use due to favourable propagation characteristics, which facilitate good range performance and angular resolution at reasonable cost. In the aeronautical sector, ICAO specifies minimum range resolution and target discrimination, which impacts on power and antenna beamwidth. This limits the scope for migration to higher frequency bands inasmuch as range would be much more limited at higher frequencies; however, since for primary radar the regulatory provisions generally relate only to the performance requirement (but not to the technology), manufacturers have considerable leeway to develop more spectrum-efficient ways of meeting the performance requirement within these bands.

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22 FCC, "Public Safety/Private Partnership", at: http://www.fcc.gov/pshs/public-safety-spectrum/700-MHz/partnership.html

Research undertaken in the UK has confirmed there is scope to benefit from technological improvements that would reduce radar out-of-band emissions, and also to make further improvements to pulsed radar designs in the future. This could reduce the frequency separation required between primary radars and could enable a reduction in the total bandwidth required (up to 30% in a typical practical scenario), potentially releasing spectrum for other uses[23]. Long pulse non-linearly frequency modulated (NLFM) waveforms were identified in the UK study as offering the best combination of spectrum efficiency and operational effectiveness. These could be developed within 6 years according to the study, which would be consistent with procurement and mid-life upgrade schedules for civil and military air traffic management. The actual time frame to full deployment would, of course, depend heavily on the degree and nature to which the need for migration were reflected in regulatory and public policy decisions, including procurement policies.

More minor changes, such as upgrading of older magnetron radars to co-axial magnetrons or reducing the pulse bandwidth in existing Travelling Wave Tube (TWT) radars, could also help. A programme to replace aging magnetron radars with more spectrally efficient solid state technology is already underway in some countries (e.g. the UK).

Similar arguments apply in the maritime sector, although the situation is more complicated in that primary radar is installed on many vessels (indeed it is an IMO requirement); hence, unilateral upgrading on a country by country basis is not feasible. Recent tightening of operational requirements by IMO[24], as well as the demand for low cost equipment for leisure craft (which limits scope for new technology deployment) also act as constraints on the degree to which spectrum efficiency could be enhanced in this sector.

3.4 Summary

In summary, the application of new technology by public sector users offers the following potential benefits:

- Enhanced capability to deliver public services, as legacy systems are replaced by more technically efficient systems, and as the number of devices needed to meet a given operational requirement is reduced;

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23 see "Study into Spectrally Efficient Radar Systems in the L and S Bands - Short Report for Ofcom Spectral Efficiency Scheme 2004 – 2005, by BAe Systems, July 2006.

24 In 2004, IMO revised the performance standards for radar, increasing the specification in terms of size of detectable target and detection probability.

- More opportunities for sharing among users through the use of more intelligent systems; and
- The potential for releasing spectrum that is no longer needed because operational needs can be satisfied more efficiently.

Public sector users will tend to need incentives beyond enhanced service capability to adopt new technology (in light of budget constraints). This issue is addressed in Section 4.5.3.4.

4 Policies for improving the use of spectrum by the public sector

This chapter explores economic and policy mechanisms that hold the possible prospect of enhancing the effectiveness and efficiency of spectrum usage by the public sector going forward.

There are two primary schools of thought as to how to improve these arrangements. One of these would argue that it is necessary to mandate periodic review of spectrum allocations, and to either justify their allocations or relinquish them. Another school of thought argues that public sector users, including defence and emergency services, need stronger incentives in order to encourage cost-conscious use of spectrum. Several approaches to strengthening incentives have been attempted (see Section 4.5), notably including the UK's implementation of market-inspired mechanisms for public sector spectrum users similar to those applicable to commercial spectrum users.

We do not see a fundamental incompatibility among these approaches. Enhanced administrative controls are a necessary first step, whether the ultimate goal is to strengthen incentives or not. Market mechanisms appear to offer substantial additional efficiencies, but experience with them to date is still limited, and they are unlikely to apply to all Member States nor to all bands.

Section 4.1 provides an overview of the policy issues to be considered. Section 4.2 explores the importance of maintaining adequate planning data as regards current and likely future spectrum use. Section 4.3 explores the use of administrative means to improve spectrum management in the public sector, as exemplified by the Netherlands. Section 4.4 discusses the implications of flexibility as it relates to spectrum use in the public sector. Section 4.5 evaluates the use of means to strengthen incentives for cost-conscious use of spectrum, including the use of market-inspired mechanisms as exemplified by the approach taken by Ofcom in the UK. Finally, Section 4.6 summarises the key aspects of the chapter.

4.1 Overall policy considerations

Improvements to spectrum policy and regulation in the public sector should seek to achieve the following high level objectives:

- Delivering greater economic and societal value per unit of spectrum used, for example, by means of:
    - Enabling better and/or lower cost public sector service delivery by means of more effective spectrum use or (for some services) by supporting cross-border operation;

  - Reallocating/reassigning spectrum to higher value uses/users, whether within the public sector or between public sector and private or commercial uses. This might be achieved by sharing spectrum more intensively or by releasing spectrum for other public or private sector users;

  - Achieving changes in spectrum use in a timely and cost effective manner; and

  - Supporting investment and innovation in activities that use spectrum.

- Achieving EU-wide objectives with respect to:

  - Public sector service delivery, such as the Single European Sky initiatives around air traffic management[25], public protection and disaster relief initiatives[26], rail transport[27] and road transport[28]; and

  - Harmonisation of frequency use for public and non-public sector users to achieve cross-border provision of services and scale economies in equipment production, and to minimise interference between national systems .

All the main spectrum management functions need to be considered, namely:

- spectrum *allocation*, and especially the balance of allocations between public sector and non-public sector use;

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25 The use of spectrum by air transport mainly concerns air traffic management (ATM). ATM systems are covered by the interoperability Regulation 552/2004. In order to improve the use of spectrum, an implementing rule on voice channel spacing was adopted by the Commission regulation (EC) No 1265/2007 of 26 October 2007. See also the Commission's Communication on Single Sky II at http://ec.europa.eu/transport/air_portal/traffic_management/ses2/doc/communication/com_2008_0389_1_communciation_en.pdf

26 Europe has taken several measures to ensure that emergency and public safety service (E&PSS) organizations have the communications resources they need. In 1996, CEPT with Decision ERC/DEC/(96)04 produced a harmonized allocation of PSS spectrum. This resulted in widespread adoption of Europe-wide PSS communications systems using either TETRA or Tetrapol. In 2008 the Commission published a Communication on "Reinforcing the Union's Disaster Response Capacity" (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0130:FIN:EN:PDF) and CEPT has adopted ECC decision ECC/DEC/(08)05 on the harmonization of frequency bands for the implementation of digital Public Protection and Disaster Relief (PPDR) radio applications in bands within the 380-470 MHz range.

27 The European Rail Traffic Management System (ERTMS) has been supported by the European Commission to create unique signalling standards throughout Europe. It aims at making rail transport safer and more competitive. See http://ec.europa.eu/transport/air_portal/traffic_management/ses2/doc/communication/com_2008_0390_1_proposal_regulation_en.pdf

28 The efficiency of road transport and safety of all road users can be improved using Intelligent Transport Systems (ITS) The European Union's eSafety and intelligent car initiatives involve the use of spectrum for anti-collision radars and to deliver information about cars over wireless broadband networks.

- spectrum *assignment*, including the process of making public sector assignments, and ways of planning and co-ordinating assignments within public sector allocations;
- the *establishment*, *monitoring* and *enforcement* of rules aimed at avoiding harmful interference; and
- spectrum *reallocation* or *refarming* to or from public sector use.

Public sector spectrum use is typically managed administratively. In particular, administrative decisions have determined:

- Allocations, and the balance between public and non-public sector allocations;
- The assignment of specific frequencies to specific public sector users;
- The extent and nature of sharing in bands allocated to public sector use; and
- Refarming of spectrum between public and non-public sector uses.

Outcomes from administrative approaches to spectrum management depend primarily on (1) the information used in making decisions, (2) the efficiency and effectiveness of administrative processes (3) the flexibility users have to adapt to changing circumstances within any administrative constraints, and 4) the incentives users face to maintain or change their spectrum use.

There has been reform in all of these areas with respect to the management of private sector spectrum at national and international levels. At a national level, national frequency plans have been published, and in some cases information on assignments has been made available on-line. Administrative processes have become more transparent, and assignments are generally being made in a timely manner. Incentives for more economically efficient spectrum use have been promoted through proposals for secondary trading for non-public sector users.[29] The European Commission has also launched initiatives to evolve to technology-neutral and service-neutral spectrum allocations in order to increase the flexibility of spectrum use.[30]

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29 Communication on a market based approach to spectrum management COM(2005)400 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0400:FIN:EN:PDF; The proposal for a Directive to Amend the electronic communications framework COM(2007)697. http://ec.europa.eu/information_society/policy/ecomm/doc/library/proposals/697/com_2007_0697_en.pdf

30 European Commission Communication COM(2007)50. Rapid access to spectrum for wireless electronic communication services through more flexibility. 8 February 2007. *{often referred to as WAPECS - Wireless Access Policy for Electronic Communications Services}.*

We need to consider whether similar reforms, or different but complementary reforms, are required as regards public sector spectrum management. In the sections below, we address the following questions:

- Is the information used to manage public sector spectrum sufficient?
- Are administrative processes efficient and effective?
- Do users have sufficient flexibility to adapt to changing circumstances?
- Where users are able to change their behaviour, do they face incentives to take actions that will promote efficient and effective spectrum use?

Achieving improvements is not likely to be quick or easy. Many sector-specific factors militate against rapid improvements in economic efficiency. For example:

- Defence and emergency services users typically are funded out of budgets that are based on their respective missions, not on potential benefits to society from using less spectrum, or from sharing spectrum with other users. Moreover, much equipment has a very long life cycle.
- The emergency services sector is comprised of a great many small, operationally independent organisations.
- Maritime and aeronautical spectrum users include both commercial and leisure craft. Operators of smaller craft are likely to strongly resist upgrades to electronic equipment, which again implies a long upgrade cycle.

This chapter reviews an array of policy options that might be implemented to promote optimal spectrum use by the public sector. The policies suggested are in many cases complementary to one another. Some of these are implemented in some EU Member States, but few Member States have attempted a comprehensive overhaul of spectrum management in the public sector to date.

A number of the changes evaluated in this chapter could only be effective if implemented in conjunction with corresponding changes in overall public sector management (e.g. changes in working practices) and public sector budgeting. These complementary changes go well beyond the spectrum manager's brief.

The policies reviewed in this chapter feed into our recommendations, which appear in Chapter 5.

4.2 Is the information used to manage public sector spectrum sufficient?

Effective management of the spectrum resource requires information on

- Current spectrum use: who is allocated and assigned what spectrum, in what location, using what type of equipment/technology and subject to what restrictions?
- Expected future use: what are future requirements given current trends in use, expected new applications, and technology developments?
- Potential conflicts in demand and the relative benefits and costs that would be associated with alternative uses of spectrum: what are the potential constraints on changing spectrum use, and the costs of relaxing restrictions where possible (e.g. by investing in new equipment, or by relocating transmitters)?

We find that information in all areas could be improved and suggest that this would improve the quality of administrative decision making. Our specific recommendations are given in Chapter 5.

4.2.1 Current use

In many countries, even basic information on current public sector use is sometimes incomplete, not regularly verified and/or not readily available to the public sector entity which is responsible for spectrum management.[31]

4.2.1.1 Spectrum allocations

At the European level, information on spectrum allocations and applications in all 27 Member States and some other CEPT countries is reported in the ERO's *European Frequency Information System (EFIS*). Since the beginning of 2008, EFIS has been based on Decision 2007/344/EC[32] which requires that information about individual rights of use be recorded in EFIS as of 1 January 2010.

EFIS data is useful, and serves many different needs. There is, however, considerable variation in the level of detail provided by individual countries, particularly with regard to military spectrum use, as shown in Table 2. In some cases, no information on military use is provided at all; in others, there is no indication of the type of use (e.g. aeronautical, fixed, land mobile). This information is essential for assessing the potential

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31 The level of detail of the information available to the spectrum management authority might be greater than that available to the general public, but less in some cases, than that available to the public sector spectrum user, due both to different sets of needs and to security requirements.

32 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:129:0067:0070:EN:PDF

for sharing the spectrum with other public sector or commercial uses. Better defined and more complete information is arguably required to provide a reliable base for making allocation decisions, particularly at an international level.

Table 2: Comparison of information provided through EFIS on military spectrum use

Austria	★★	Germany	★★★	Netherlands	○
Belgium	★★	Greece	★★	Poland	★★
Bulgaria	★	Hungary	★★★	Portugal	★
Cyprus	★★	Ireland	○	Romania	★
Czech Rep	○	Italy	○	Slovakia	★
Denmark	★★★	Latvia	★★	Slovenia	★★
Estonia	★	Lithuania	★	Spain	★★
Finland	★	Luxembourg	★★	Sweden	★★★
France	★★	Malta	○	UK	★

Key: ○ No information provided on military use
★ Military bands identified but no usage details provided
★★ Limited usage details provided
★★★ Extensive usage details provided

The utility of EFIS would clearly be improved if all administrations were to provide a level of detail comparable to that of Denmark, Germany, Hungary and Sweden; however, the most immediate priority is to ensure that all administrations at least provide a clear indication of which spectrum is used by the military in their respective territories.

There is also some inconsistency in the terminology used, e.g. tactical radio relay systems may be referred to as land military systems or point-to-point links by some administrations. Whilst this is less of an issue than the variability in information provision, there would be merit in developing a consistent approach to application definitions to facilitate comparisons between countries and identify scope for possible future spectrum band harmonisation opportunities.

EFIS has been progressively enhanced over the past few years, largely in recognition of the needs of commercial users of spectrum. The need for good, cross-country comparable data is no less urgent in the public sector.

4.2.1.2 Spectrum use/assignments

Even where there is good information on spectrum allocations, the extent of public sector use of the spectrum is not always known by either the national spectrum manager or by the spectrum user. The situation varies considerably across sectors.

Assignments to emergency services are often managed by the spectrum management authority in which case detailed and reliable information may be held centrally. We note that from 2010, information on individual rights of use will need to be recorded in EFIS; however, not all public sector users access spectrum through such rights (see section 4.3.3).

In the case of the aeronautical sector, there is a centralised European database (SAFIRE) which is used to coordinate assignments for VHF communications and assignments for radars and MF/HF communications are coordinated by national administrations through ICAO. Similarly, the IMO coordinates frequencies for international maritime communications. In addition there are national assignments that are managed locally.

By contrast, for sectors where allocations are typically managed by the user, it is not always clear what information is held on the extent and nature of use. Two Member States where public sector spectrum use has been subject to a spectrum audit are the Netherlands and the UK. In both cases, it has been found that users often do not know what spectrum they actually use, nor do they know the technical and geographic characteristics of that use within their allocations. In the UK for example, the Ministry of Defence is now engaged in a four year plus process of collecting information on all spectrum use in the bands it manages. This data had not been previously collected. The information will be used to create a central database of assignments and of other spectrum management information.

If information on the actual use of spectrum allocated to the public sector is not known, then the possibilities for changing that use, or of possibly sharing or releasing the spectrum to other public and non-public sector users, cannot be determined. Accurate detailed assignment information is essential if public sector spectrum is to be planned and coordinated efficiently. Ideally, this information would be integrated with the spectrum manager's database of assignments for non-public sector users, to facilitate efficient planning and sharing of all of the spectrum. The absence of reliable central databases of assignments for public sector use in many countries means that planning tolerances are larger than necessary to avoid harmful interference.

We anticipate that the availability of reliable databases, together with the use of advanced planning tools,[33] would offer scope to improve public sector spectrum use from a technical perspective, including scope for increased sharing of the spectrum.

Where detailed and accurate databases of public sector assignments are not available, we recommend that the Member State first conduct a spectrum audit to compile this information. Without this information, other reforms are unlikely to be effective; however,

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33 In the UK, the Cave Audit recommended that the Ministry of Defence and the civil aviation authority use a joint planning tool for formal coordination in shared aeronautical bands.

it is not clear that audits alone achieve the optimal or appropriate level of spectrum release. Our overall assessment is that the implementation of systematic audits by an appropriately positioned, integrated and impartial body should be viewed as a best practice. Beyond this, we see scope for additional overall economic and social benefit from the use of financial incentives, as discussed in Chapter 5.

The issue of who may access information collected as part of spectrum audits will need to be addressed given the security and safety related aspects of many public sector uses. The spectrum management authority should have access to sufficient information to enable an integrated approach to spectrum management, but security clearances may be required for spectrum management authority staff if they are to access information on military and other sensitive assignments.

The public release of information on public sector spectrum use will in some cases need to be limited on security grounds, particularly as regards detailed assignment information; however, we note that the release of information on public sector allocations and assignments in some countries (e.g. Australia) does not appear to have caused any problems. Once assignment data is stored in electronic databases, then security controls could be used to limit access where necessary.

4.2.2 Future use

At a national level, plans for future public sector spectrum use are being developed in some countries and are being integrated into planning for non-public sector use; however, this practice is not yet widespread. Such plans are necessary because of spectrum scarcity.[34] Any new requirements from either the public or the private sector have to either be satisfied using "spare" spectrum in existing allocations (which might imply the use of sharing), or else spectrum must be refarmed to accommodate new uses. Future plans for public sector use are therefore highly desirable for national planning, and could also be a useful input to the spectrum management authority for negotiations in international fora (e.g. ITU, CEPT, and other European institutions) when future allocation policies are debated. Notably, these future plans should be a key input to the European Commission in connection with its international responsibilities, especially as regards preparing European positions for the WRC (see Section 4.1 of the Annex to this report).

The spectrum policy and strategy for the aeronautical sector in Europe is developed by the Aeronautical Spectrum Frequency Consultation Group (SFCG), which has been in existence for the last two to three years. This group comprises senior representatives from the European Civil Aviation Conference (ECAC), and is supported by Eurocontrol.

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34 Most spectrum below 15 GHz is fully allocated and heavily used.

It produces two main outputs: (1) the European Aeronautical Common Position (ECAP), which is an input to WRC and ICAO, and (2) the European Aeronautical Spectrum Strategy. More generally, the UK regulator Ofcom recently published a study on future demand for spectrum from the transport sector as a whole over the next 20 years.[35]

The spectrum requirements of NATO are set out in the NATO Joint Civil and Military Frequency Agreement (NJFA), and the harmonised NATO bands stipulated in the NJFA are incorporated into the European Table of Frequency Allocations and Utilisation of the European Communications Committee (ECC) prepared and updated periodically by CEPT. This table[36] shows the main (fully or partly) harmonised allocations and utilisation of spectrum across Europe. One of the search options in EFIS relates to this table, along with each of the national tables. NATO bands are annotated as "harmonised military bands". NATO does not publish a long term strategy document.

In the case of the emergency services, the Forum for Public Safety Communication Europe (PSCE) has produced a spectrum harmonisation initiative addressing the need for additional spectrum for mobile broadband data communications in the area of public protection and disaster relief across Europe.

Within the public sector, civil and military requirements should ideally be examined together, particularly for new applications like unmanned aircraft where "new" spectrum may be required. Also, the public safety sector could work more closely with the defence forces to gain access to their spectrum during public emergencies (e.g. terrorist attacks), which might offset the need for more spectrum from elsewhere.

In our view, Member States that take an overall, strategic view of their management of their public sector spectrum are far better positioned to manage their spectrum effectively than those that do not (and thus must manage reactively to needs as they emerge). We therefore call special attention to the importance of a comprehensive program to identify future spectrum needs in advance, since it is apparently not widespread among the Member States. We consider it to be a best practice.

4.2.3 Information used in making allocations

Responsible regulation and oversight of the spectrum resource requires periodic checking of whether spectrum delivers maximum economic and social benefit. To the extent that spectrum is not allocated, managed and assigned in a way that maximises economic and social welfare, two principal problems can result. First, the public interest is demonstrably not served if the existing use does not generate the maximum social benefit. Secondly, there is an arguably further-reaching problem: namely that innovation

35 http://www.ofcom.org.uk/research/technology/research/sectorstudies/transport/
36 http://www.erodocdb.dk/docs/doc98/official/pdf/ErcRep025.pdf

and development of new uses, standards and socially valuable services are hindered or distorted if spectrum is not made available for new uses.

The balance between public sector and non-public sector allocations has largely been determined over time by administrative decisions made at an international level (e.g. in international bodies such as ICAO, IMO, and NATO that make representations to the ITU), European level and national level. These decisions are informed by technical analysis and an appraisal of users' spectrum requirements (generally assuming a zero spectrum price). While experience suggests that so far there has been sufficient provision for public sector use, it is less clear that this has resulted in sufficient spectrum being made available for non-public sector use. Reallocations to non-public sector use have typically been made in response to commercial and political pressure for additional spectrum to accommodate new applications, such as cellular telephony, broadband wireless access, fixed links and commercial satellite uses.

The absence of transparent information on public sector use, together with the significant costs of changing public sector use when necessary, means that this evolutionary approach to achieving the balance between public and non-public sector spectrum allocations has not been well informed. It is therefore unlikely other than by chance that the current balance between public and non-public sector allocations is optimal.

Better outcomes might be achieved through use of better information on the relative costs and benefits of different spectrum uses. Cost/benefit analysis is sometimes undertaken to inform allocation decisions for commercial applications (See for instance the cost/benefit analyses undertaken to inform decisions concerning the allocation of UHF spectrum – the so called digital dividend – in the UK[37] and France[38] and the cost/benefit appraisal undertaken for Europe as a whole.[39]). This analysis is not often applied in the context of spectrum allocations to the public sector.

One recent example, however, is the impact assessment undertaken by CEPT on the harmonised allocation of spectrum to Intelligent Transport Systems (ITS). The Impact Assessment compares the benefits of an allocation at 5.9 GHz and 6.3 GHz to ITS with the opportunity cost of the spectrum when used for alternative applications.[40] They concluded that a 1% reduction in road accidents within a decade is sufficient to justify the allocation to ITS. The use of an Impact Assessment is an innovation, but illustrates that such assessments can be applied to public sector spectrum use. Another example is an estimate by Eurocontrol of the potential financial costs and spectrum benefits of

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37 http://www.ofcom.org.uk/consult/condocs/ddr/statement/

38 http://www.analysysmason.com/PageFiles/4324/Valuation%20of%20the%20digital%20dividend%20in%20France%20(English%20Version).pdf

39 http://www.spectrumstrategy.com/Pages/GB/perspectives/Spectrum-Getting-the-most-out-of-the-digita-dividend-2008.pdf

40 http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP020.PDF

moving from a flight level of 24,500 feet (FL 245) to 19,500 feet (FL 195) for 8.33 kHz communications on a European basis.[41]

By contrast, analysis of options for allocating harmonised spectrum for wideband and broadband systems used for public protection and disaster relief (PPDR) did not involve an impact assessment.[42] So far, no consensus has been reached on the way to proceed in this area. This could be an instance where an impact assessment would help render the choices involved transparent and thus assist in moving the debate forward.

Good practice requires that allocation/refarming decisions are supported by a qualitative and where possible quantitative analysis of the costs, benefits and other impacts of competing public sector uses or competing public sector/non-public sector uses of spectrum.

4.3 Are administrative processes efficient and effective?

Leaving aside the availability and quality of information (addressed above), the efficiency and effectiveness of administrative processes depends on their speed, transparency, operating costs, and the costs they impose on third parties. These in turn depend on institutional arrangements and whether processes are automated or not. A further consideration in respect of spectrum management is the clarity of licensing arrangements. We discuss these issues below.

4.3.1 Institutional arrangements

Institutional arrangements can have an important role in determining the efficiency and effectiveness of administrative processes. There is no single organisational approach to spectrum management within the European Union. In some countries such as Finland and Sweden, the National Regulatory Authority (NRA) manages all spectrum-related issues. The organisation responsible for spectrum matters can also be a Government Department (usually the Ministry of Communications/Telecommunications) as in Cyprus or Spain. In other countries, spectrum management is shared between different organisations including the NRA, government department(s) and in some cases other administrative bodies.

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41 http://www.eurocontrol.int/ses/gallery/content/public/docs/ru/SES_IOP_VCS_JMA_v2.0.pdf

42 Two bands have been identified – 380-400 MHz and 4940-5925 MHz but in both cases there are sharing and compatibility issues to be addressed. Public Protection and Disaster Relief Requirements, ECC Report 102, CEPT, January 2007.

Where spectrum management is fragmented between different bodies, there is often but not always a committee that coordinates public sector use and requirements. Such committees could in principle foster best practice for the whole of the public sector; in practice, however, they appear to have tended to focus on technical issues, and to deal reactively with competing public sector spectrum demands. In order for an integrated strategy for the management of the entire spectrum to be effective, the body responsible for private sector spectrum management should participate in such a committee.

Whether the committee structure is the best approach, as compared to either the NRA having full responsibility for spectrum management (as in Sweden) or there being a public sector spectrum manager (somewhat comparable to the NTIA in the US), is unclear. Having a single integrated spectrum management authority making final decisions about spectrum strategy for both the public and the private sector would seem likely to have advantages in terms of achieving a consistent and integrated approach, and in terms of making the best use of available skilled resources.[43]

If spectrum management were only a matter of information sharing within the public sector, it might be sufficient to simply establish suitable electronic interfaces between assignment databases; however, spectrum management in the public sector entails much more than this. There needs to be a forum in which sharing between public sector users is facilitated, and conflicts in requirements are resolved.

For analogous reasons, our perception is that it is more difficult to achieve the correct balance between public sector and non-public sector spectrum allocations in countries where management of these sectors is widely separated in an organisational sense.[44] Sound planning requires, rather, that the balance between public sector and non-public sector spectrum be overseen by an impartial organisation that can make objective decisions, while retaining credibility with both communities.

In some cases, the management of public spectrum is delegated to sectoral bodies (who are sometimes the spectrum user). A problem that this can lead to is that the manager may seek to keep all of its allocation for its own use (rather than sharing/releasing spare spectrum for use by others), particularly if incentives to do otherwise are weak. It is essential to adopt institutional arrangements that separate *management* from *use*. The separation of regulatory functions from the provision of electronic communications networks, equipment or services has been found to be

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43 Where an integrated authority is impractical, it may be possible to achieve some efficiency gains in terms of staff effectiveness by means of cross training. For example, Canada routinely seconds military personnel to the national spectrum management agency.

44 This may possibly be the case in the US, for example, where government spectrum is managed by the NTIA and all other spectrum is managed by the FCC and where the Federal Strategic Spectrum Plan (2008) recommended improved federal/private sector co-ordination.

essential to effective regulation in the context of general telecommunications.[45] It is for this reason that this separation is a key element of the framework for regulation of electronic communications services in Europe.[46] This concept of separation could profitably be extended to spectrum management at the Member State level.

This separation has distinct parallels to the changes to the regulatory framework for electronic communications that the Commission put forward in November 2007, which seeks to "[strengthen] the NRA's independence by setting standards for the dismissal of the head of the NRA, limiting the possible influence of other public bodies on the NRA's day-to-day management, and ensuring that it has its own independent budget and sufficient human resources…"[47] Member States might profitably apply the same principles to the Spectrum Management Authority (SMA).

4.3.2 Use of Information Technology (IT)

Many processes of coordination between public sector users (and between non-public sector and public sector users) appear to be undertaken at a manual level if at all. Automation of these interactions is held back by many factors, including the absence of complete and accurate assignment databases. Where sufficiently reliable and comprehensive databases exist, it is possible that requests for assignment information and assignment processes could be automated. This would save both time and cost, and should lead to more intensive use of the spectrum. In addition, good planning tools could facilitate sharing of spectrum between different applications and users. The desirability of greater use of IT systems for licensing and spectrum management applies both to public sector and to non-public sector spectrum management.

For example, in the Annex we discuss the example of SAFIRE for VHF aeronautical communications, and also the automated approach to 70-80-90 GHz co-ordination in the US. In addition, the NTIA is working to provide a single data portal access to classified and non-classified systems, electronic access to Interdepartmental Radio Advisory Committee documents, and creation of a data dictionary that will standardise terminology used in frequency applications (see the Annex).

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45 See for example, Brian Levy and Pablo Spiller. 1994. "The Institutional Foundations of Regulatory Commitment: A Comparative Analysis of Telecommunications Regulation." Journal of Law, Economics and Organisation, Volume 10(2); . Witold Henisz. 2002. "The institutional environment for infrastructure investment." *Industrial and Corporate Change* 11(2). http://www-management.wharton.upenn.edu/henisz/papers/ieii.pdf : Witold Henisz and Bennet Zelner. Spring 2001. "The Institutional Environment for Telecommunications Investment." *Journal of Economics and Management Strategy* 10(1). http://www-management.wharton.upenn.edu/henisz/papers/hz_ieti_jems.pdf

46 As is required under Article 3, Framework Directive, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:108:0033:0050:EN:PDF

47 See document COM(2007)697 rev1.

4.3.3 Licensing

The extent to which allocations and assignments to public sector users are formally licensed varies considerably from country to country (see the Annex to this report). Use by defence is least likely to be licensed,[48] particularly where defence allocations are fully managed by the Ministry of Defence. Use by emergency services and transport are more likely to be licensed, either by the spectrum management authority or the relevant Ministry, although this is not always the case. Where licences are issued (either for individual assignments or for block allocations), they typically are in effect perpetual, with any changes or refarming being agreed subsequently on a negotiated basis.

These arrangements are in stark contrast to those that apply to commercial services, where users are licensed (unless the band is designated as licence-exempt), licences have a given duration, and increasingly notice periods for the termination of annual or rolling licences are made explicit. The potential advantages of putting in place formal licensing arrangements are that:

- User organisations are more fully aware of the spectrum that is allocated to them.
- Spectrum management authorities are able to maintain better records of spectrum usage, and thus to promote good management and public transparency.
- Technical constraints on use and protection from interference from others are explicit. This gives all parties more certainty about the interference environment in which they are operating, and allows for more efficient technical planning and co-ordination of use by the spectrum manager(s). This could be coupled with some form of certification / compliance process for equipment (akin to the R&TTE Directive for commercial equipment), which we understand does not exist currently in most EU countries, although it does in the US (via NTIA).
- The process for not renewing or terminating licences is explicit. This gives users time to plan for change. The end of the licence period often provides a useful point at which to review the options for future use of the spectrum and whether the licence conditions should be changed in some way – for example to accommodate a new service. In this regard, we note that some public sector users (e.g. broadcasters) may have time-limited spectrum licences, while others (e.g. defence) do not largely for historic reasons. Assigning licences or an equivalent instrument with a fixed end date to public sector users would be a natural complement to periodic review of their continued need for spectrum, and would contribute to efficient spectrum use.

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48 Though defence use is licenced in some countries e.g. Sweden.

- Licensing provides a mechanism for charging licences fees (so that spectrum managers can recover their costs) and is a necessary prerequisite for putting in place the market approaches to spectrum management described in the section 4.5.

Even if it is not legally possible to put in place the same licensing arrangements as those that are used for non-public sector users, there would still be considerable advantages in having the terms and conditions of spectrum access by the public sector fully documented, and in applying similar compliance requirements to public and private sector users.

4.4 Flexibility in spectrum use

If spectrum allocations (and assignments) are defined flexibly, then users can potentially change their spectrum use as their requirements change (assuming that they cause no harmful interference to other users). Allocations to the defence sector are generally defined in a technology neutral manner and often allow considerable flexibility in the services/applications that may be deployed. There are greater service and technology restrictions on spectrum allocated to transport and public safety users. At the last WRC, the aeronautical sector sought to liberalise many of its allocations, principally by allowing deployment of communication systems (where there is substantial demand growth) in existing aeronautical navigation bands (where demand for navigation applications is relatively static).

More generally, there is a good case for liberalising allocations to the public sector, so that where feasible allocations are technology and service neutral in line with European Commission policy in respect of electronic communications services (e.g. WAPECs policy). The extent of liberalisation that is optimal will vary from band to band, depending in part on the nature of the spectrum band harmonisation required to meet requirements for cross border operation and coordination and in part on the scope for sharing between different applications.[49]

Public sector users' rights of access typically have sufficient flexibility to permit sharing with other users (public or private sector); however, because of the need to maintain the integrity of the public service, technical analysis of the implications for and constraints on sharing may often be required.

In addition, while there is potential to share public sector allocations where public sector use is intermittent (see sections 3.2.1 and 3.2.2), the incentives for public sector users to open up their allocations in this way are not strong. Sharing may impose direct costs on the incumbent user, may foreclose future opportunities to use the spectrum, and

49 The trade-offs between harmonistaion and flexibility are discussed in ECC Report 80.

may increase the risk of interference. There is thus a risk that the incumbent will accept far less sharing than is societally optimal, because the benefits accrue to society as a whole, while the incumbent experiences only costs and no benefits (especially if spectrum is perceived as being costless, and there is no financial benefit to sharing). Incentive issues are discussed more fully in the next section.

4.5 Incentives for efficient spectrum use

The improvements to administrative processes that we have discussed up to this point do not address whether the public sector user faces any incentive to change, nor do they address the constraints on and change and the disincentives to change posed by lack of funds, budgetary rules, procurement processes, employment contracts and so forth.

Under an administrative approach to spectrum management, spectrum users have incentives to hoard spectrum, as there is no assurance that more spectrum will be reserved for them in future, nor is there assurance that any spectrum released for others will be returned at some future time. These incentives to hoard may be weakened by having to pay for spectrum access, but it is often the case that major public sector spectrum users do not pay any spectrum fees; moreover, fees are often set at levels far less than those required to recover the opportunity cost of spectrum (see the Annex).

To continue to deliver greater economic and societal value per unit of spectrum over time, it is necessary to change the incentives faced by public sector spectrum users. There are number of ways in which this could be done:

- Limit the quantity of spectrum available to the public sector spectrum user so that they are motivated to invest in new technologies or to acquire spectrum in the same way as the non-public sector spectrum users to the extent that they need to support service growth and/or development;
- Make the users publicly accountable for their spectrum use and for their associated technology choices;
- Provide economic rewards/penalties for more or less efficient spectrum use.

4.5.1 Quantity controls

Quantitative restrictions would comprise limits on the amount of spectrum a user may have reserved for its use. Any additional spectrum that may be required would have to be either justified by detailed proposals, or acquired in competition with commercial users.

This is clearly a rather blunt instrument, as it assumes that the current position gives an indication of the "appropriate amount" of spectrum required; thus, it does not seek to achieve reductions in spectrum use. This is in effect what is happening in the case of the aeronautical sector, for example, where it seems unlikely that new internationally harmonised allocations will be made available. The sector has sought additional flexibility within its existing allocations and has adopted narrower bandwidth channels where congestion is acute at VHF.

4.5.2 Public Accountability

Earlier in this chapter we discussed the role of spectrum audits as a necessary first step to improving public sector spectrum use. We also noted the potential conflict of interest within government concerning spectrum management and use. One way this issue is dealt with in regulation more generally is for consultation and decision processes to be conducted transparently with publication of key documents and by allowing other users and the public more generally to comment on proposals.

Applying this approach to public sector spectrum use would involve publication of the results of spectrum audits and users' plans for future spectrum demand and/or release. This would help make other spectrum users aware of potential opportunities for sharing, and would enable third parties to indicate their interest in sharing opportunities and to comment on any findings relating to the adoption of new more spectrally efficient technologies by the public sector. Making the results of the audit a matter of public record potentially gives more focus to any necessary changes, and puts pressure on public sector spectrum users to adopt good practices and suitable technologies.

A limitation in applying this approach to certain public sector uses is that publication of sensitive information could be incompatible with national security requirements. However, we note the UK Ministry of defence recently published a consultation document on its spectrum strategy.

Where public sector users are required to justify their spectrum holdings, there must be an independent third party that is competent to determine what is justifiable use. The spectrum user may have incentives to withhold information or to mislead others. This reinforces the need to separate spectrum management from spectrum use in the public sector, as discussed in Section 4.3.1.

4.5.3 Economic incentives

Economic incentives are generally best provided through markets. The purpose of market-inspired approaches to spectrum management in the private sector is to use prices to provide users with incentives to demand spectrum at the level that maximises

economic and social welfare. This is in contrast to the administrative approach in which spectrum requirements are expressed assuming the spectrum is in effect costless or "free". Demand will be less if a non-zero price is charged.

For the private sector, the use of spectrum auctions is well established. The European Commission has advocated expanding the use of a market-based approach to spectrum management, including the use of secondary trading for non-public sector users. A key question is the degree to which these market-inspired approaches have merit in the context of public sector use. To assess this we consider the following questions:

- Should the public sector pay a price for spectrum that reflects its opportunity cost?
- If so, should the opportunity cost be set by the regulator or the market?
- Should the public sector be permitted to sell (i.e. trade) their spectrum holdings?
- Should financial incentives be used to refarm spectrum?
- Should public sector accounts and procurement processes take account of the opportunity cost of spectrum much as they do the cost of other resources (e.g. labour, buildings)?

The following sections take up these questions in turn.

4.5.3.1 Should the public sector pay a price for spectrum that reflects its opportunity cost?

The public sector has typically been given or gifted the spectrum that it uses (which is to say that the spectrum has been provided at no cost, in much the same way that state owned land has often been gifted for public sector purposes), and is expected to use the resource to deliver outputs that are specified through the political process. There is not, however, a fixed relationship between spectrum and the output of public sector agencies. These agencies have choices over the amounts of other complementary inputs they may purchase (e.g. radios and transmission equipment, transmission sites and the like), all of which affect their spectrum demand. Other complementary inputs are not free; consequently, there will be a tendency to use more spectrum (which is either free or low cost) and less of other inputs where such choices exist. If spectrum is scarce and so has a non-zero opportunity cost, then gifting spectrum will predictably result in an economic distortion and an inefficient use of the resource.

As a general rule, welfare is maximised by setting input prices equal to opportunity cost[50] and targeting policy interventions on the desired outputs. Leaving aside practical issues for the moment, there is a good case for the public sector to pay a price for spectrum that reflects its opportunity cost, just as they pay such prices for other inputs (such as buildings, office supplies, or personnel). There are different ways in which this payment could be implemented; the public sector could bid for spectrum at auction, could buy spectrum through trades, or could pay a price set by the regulator (a practice known as *Administrative Incentive Pricing*, or *AIP*).

For these policies to be beneficial, however, changes may be required in the way that the public sector agencies operate. It is often argued that charging for spectrum use by the public sector is just a "money go round" with no beneficial effects. This argument is correct if the public sector user cannot benefit from any saving in its spectrum costs. This means that for market-inspired mechanisms to be effective in the public sector, budgetary arrangements need to be sufficiently flexible to allow public sector organisations to "profit" from economising on spectrum use, including the ability to increase or decrease their expenditure on spectrum use (where this is thought to be necessary) within their overall budget constraints. New institutional arrangements and budgetary processes that provide commitments to the public sector spectrum user not to remove gains from more efficient spectrum use for a given period of time (analogous to price caps on utility charges) will be required. In addition, there may need to be one-off budget adjustments when the public sector user must initially pay a significant price, assuming that the level of public sector outputs must be maintained.

4.5.3.2 How should the price be set?

If the public sector is to pay a price reflecting opportunity cost, we next consider whether the price should be set by the regulator or by the market through trading or auctions. Prices set by markets are generally more efficient, but there are some practical issues to consider.

If a market mechanism were used, then:

- The public sector user would have to be formally licensed so that payments were made in return for an asset that could later be re-traded. We note there are examples of the public sector acquiring spectrum through trades in Australia (see the Annex).
- Public sector bodies would need to plan their future spectrum requirements so that the costs are built into their budget plans. Budget flexibility and the potential

50 Peter Diamond and James Mirrlees. 1971. "Optimal taxation and public production 1: Production efficiency and 2: tax rules". *American Economic Review*, Volume 61.

to keep a share of the gains from market transactions are also required as discussed above.

- Public sector requirements will be intermittent, requiring transactions from time to time; however, the public sector users may not have the expertise required to bid at auction or to trade spectrum. We note that in the UK it has been suggested there might be a single entity set up to act on behalf of the public sector in spectrum markets for an interim period, at least until the necessary expertise and experience is built up.

- Exceptional circumstances in which these mechanisms did not apply would need to be identified, e.g. if there were a pressing demand for spectrum to deliver safety or security critical services.

In the case of prices set by the regulator, the practical issue of setting the price needs to be addressed. Such prices have been set in only a few countries (e.g. the UK, Canada). While the prices obtained are approximate it should be noted that they are significant and appear to have had an effect on user behaviour (see Table 2). In the UK, the Ministry of Defence currently pays £50m for its spectrum access, and this will increase by around 50% over the next two years. The Ministry of Defence has a programme of audits for all its spectrum holdings, and has so far announced firm plans to release spectrum at 406-430 MHz and 3400-3600 MHz.

Table 3: UK spectrum releases since 2004 that are linked to AIP

Original user	Spectrum released	Bandwidth	Year
MOD	2290-2300 MHz	10 MHz	2004
MOD	8400-8500 MHz	100 MHz	2004
Radio astronomy	37.75-38.25 MHz	0.5 MHz	2007
Radio astronomy	Remove constraints on services at 150.05-152 MHz	2 MHz	2007
Radio astronomy	Remove constraints on services at 80.5-82.5 MHz	2 MHz	2007
Radio astronomy	10.6-10.68 GHz	80 MHz	2007
Radio astronomy	Remove constraints on services at 31.5-31.8 GHz	300 MHz	2007
Police in Scotland	Non-contiguous spectrum in 450-462.5 MHz	1 MHz	2007

Source: Spectrum Framework Review for the Public Sector, Ofcom, January 2008[51]

51 http://www.ofcom.org.uk/consult/condocs/sfrps/statement/statement.pdf

4.5.3.3 Should the public sector be permitted to sell (i.e. trade) their spectrum holdings?

For public sector users to be able to trade their spectrum holdings, their holdings first need to be formalised as tradable licences.

Once this is done, there might be a concern that public sector users would sell vacant spectrum when they faced a budget shortfall, but would then come back to the government to ask for additional funds to finance new purchases when the spectrum were required to deliver a particular output, thus potentially undermining the incentives of the public sector user to responsibly manage its budget. This has not happened in practice. In Australia, for example, public sector spectrum is tradable but there have been no sales by the public sector. This is partly explained by the view that because the opportunity cost of tradable spectrum is not accounted for in public sector budgeting, users do not regard its as a valuable resource that they should actively manage. For this reason, the Australian government is looking at applying AIP to government spectrum use.

4.5.3.4 Should financial incentives be used to refarm spectrum?

Refarming spectrum from public sector to non-public sector use imposes costs on the public sector user. The public sector user is likely to be reluctant to incur these costs, because they typically have not been considered in the budgeting process, and do not necessarily directly benefit the public sector user. Arranging for those who benefit from the spectrum release to pay for some or all of these costs can assist in achieving refarming in a timely manner.

There are a number of ways in which this can be done:

- Setting up a refarming fund financed by spectrum fees paid by new users, with a bridging loan from the government (e.g. France, Japan);
- Using revenues from the auction of spectrum that is to be vacated to fund the migration. In this case, the government determines the level of compensation to be paid in advance of the auction (this has been done in the US), so that the incumbent does not try to extract all of the auction revenues; or
- Requiring new users in the band to negotiate with the incumbents (as has been used in Australia and the US). To avoid hold-up problems in which incumbents seek to obtain the full value of the right, it is necessary to place time limits on incumbents' rights.[52]

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52 "Efficient relocation of spectrum incumbents" , P Cramton, E Kwerel and J Williams, October 1996.

All three approaches are likely to require the involvement of the Ministry of Finance inasmuch as they result indirectly in less revenue being paid to the central fund; however, the potential economic and social benefits that flow from spectrum released for new applications can be significant.

Financial incentives for refarming funds could be particularly useful in the case where spectrum needs to be cleared on a harmonised EU basis. Because most spectrum below 15 GHz is fully allocated and heavily used, finding new bands for public and non-public sector services on a harmonised basis across Europe is inevitably going to involve moving some users. Financial incentives could therefore aid the timely introduction of harmonised European allocations. For example, in some EU countries public sector use potentially blocks the full use of the 2.6 GHz and 3.5 GHz bands allocated for future mobile services. In addition, an immediate issue for public safety services is the identification of harmonised spectrum for broadband services. Spectrum in the 380-400 MHz band is a potential candidate, but this cannot be cleared throughout Europe because of existing military use. Again, the availability of funds for refarming in Member States where there are obstacles to the release of the spectrum could help address this situation, as could the promotion of greater spectrum sharing between the military and public safety authorities.[53]

Refarming funds are typically used selectively by spectrum managers in circumstances where the net benefits of refarming are substantial. The existence of a refarming fund potentially creates incentives on the public sector spectrum user to "hold out" for a large payment. This tendency may be mitigated by the formalisation (and limitation) of public sector users' rights of access, by the separation of public sector spectrum management from spectrum use, and by having clear rules about the basis for compensation. In some Member States, refarming funds may be unnecessary because change can be achieved administratively in a timely manner, while in others it may be impractical because such "hypothecated" revenues are not possible. Nevertheless, we feel that selective use of refarming funds or explicit budget allowance for refarming could be valuable in achieving harmonised spectrum release.

4.5.3.5 Should public sector accounts and procurement processes take account of the opportunity cost of spectrum?

One approach to recognising the value of the spectrum resource used by public sector agencies would be to include the capital value in their balance sheets. This assumes that the public sector as a whole has adopted resource accounting (which is not the

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53 One could perhaps make an argument that funding for refarming of bands harmonised at the EU level would most appropriately be provided or managed at the European level; however, it seems to us that doing so might potentially run afoul of a thicket of Member State regulations. We therefore assume that responsibility for funding refarming should rest at Member State level.

case in all Member States), and that it is possible to value the spectrum used; however, there could be analogies here with the treatment of land and other assets of such organisations.

Spectrum demand is also linked importantly to equipment and technology choices. Few public sector users appear to take explicit account of the spectrum implications of their radio equipment purchases. This means that outcomes are likely to be less spectrally efficient than they would otherwise be. One way to address this would be to require the life cycle cost of the spectrum (ideally its opportunity cost) to be included along with the life cycle costs of equipment purchases in the appraisal of the costs of the overall system. This requires estimates of the value of spectrum over time. These might be estimated based on bids in auctions, or based on known sale or lease prices on the secondary market, or they could be derived from bottom-up calculations of the value of the spectrum to commercial services. If appropriate opportunity cost estimates do not exist or are difficult to derive, then there should at least be some public discussion of the spectrum requirement over time and of the potential alternative uses of that spectrum that would be denied access.

Complementary changes in public sector budgetary processes might be required. Budgetary rules restricting the movement of funds between capital purchases and operating costs may inhibit the adoption of more efficient equipment, because the gains in operating efficiency cannot be counted against an increased capital cost. Analogously, some public sector employment contracts might impact the effectiveness of procurement processes that seek to properly take account of the opportunity cost of spectrum. Differences in national public sector accounting and employment policies may mean that such changes are possible in some Member States, but not in others.

4.6 Summary

This chapter has evaluated the potential of an array of policy initiatives that could enhance the effectiveness of spectrum management in the public sector. We build on this analysis in Chapter 5, where we present our recommendations.

There are quite a few distinct goals in spectrum management in the public sector. On the one hand, policymakers would like to maintain and to enhance the delivery of public services, which is a particularly significant theme to the extent that these public services often play a crucial role in protecting lives, well-being, and property. At the same time, radio spectrum is a scarce resource that deserves careful and efficient management. Inefficient use of spectrum could have a negative impact on the performance of the economy as a whole.

Given the widely recognised value of these services, spectrum management authorities have generally been careful to ensure that public sector spectrum users have sufficient

resources to do their jobs. Less clear is the degree to which efficiency has been maintained. There are many reasons to believe that the most common arrangements – indefinite, costless allocations with little subsequent review – are not conducive to efficient management of the spectrum.

The discussion of policy options for reforming public sector spectrum management given in this chapter has identified a number of largely complementary policies which could be taken to address this situation. These policies are interdependent in the sense that some are a necessary pre-requisite for others to be effective. In particular, policies aimed at improving the information base for public sector spectrum management are an initial requirement. Improvements to tools used and to institutional arrangements for public sector spectrum management can build on this information base.

Improvements in the information base, and in institutional arrangements, are a prerequisite to effective implementation of policies aimed at changing incentives of public sector users so that they act in ways that promote optimal overall spectrum use.

Technological improvements lend themselves to enhanced flexibility, to sophisticated spectrum sharing arrangements, and to overall efficiency enhancements (notably in radar); however, the challenges to improved spectrum management in the public sector cannot be addressed by technology alone. A key task for spectrum management policymakers is to ensure that public sector spectrum users are incented to deploy improved technology when appropriate, and that any necessary international coordination is dealt with.

Policies that involve changing the economic incentives faced by public sector users will be most effective of accompanied by changes in public sector budgeting and procurement processes that allow users to benefit from more economical spectrum use. As we have previously noted, there is considerable variation across Member States in public sector spectrum management, and these differences may limit the practicality and effectiveness of policies aimed at changing the economic incentives faced by public sector spectrum users.

5 Recommendations

This chapter presents our recommendations for spectrum management policy and regulation for the public sector drawing on the evidence collected from country interviews and international experience (Chapter 2), in conjunction with the supplementary material that appears in the Annex, and our discussion of technical and policy options for improving spectrum management (Chapters 3 and 4).

The task of identifying best practices is substantially complicated by the interplay and the division of responsibilities among the stakeholders in spectrum management. Some determinations are appropriate to the Member State level; others, to the European Union; still others, to NATO; and others (including many aspects of aeronautical and maritime) are global in scope. Even within a Member State, it is often the case that different institutions address different aspects of spectrum management for the public sector. In this study, consistent with our terms of reference, we have attempted to take an over-arching view, identifying current or potential future best practices irrespective of which stakeholder or group of stakeholders might be in position to implement the practice in question. We have not limited ourselves to identifying best practices that the Commission has authority to implement.

The optimisation of spectrum use by the public sector has received relatively little systematic attention to date. We see many opportunities to do better, in the sense of achieving greater socio-economic efficiency and also of enhancing the effectiveness with which public services are delivered; however, we do not see a single "silver bullet". We think that a number of mutually complementary initiatives must be launched, reflecting a mix of improved public availability of information, better institutional arrangements, better management tools and planning, better technology, better incentive arrangements, and better support from related policies that are not themselves part of the spectrum management process. Schematically, this can be visualised as depicted in Table 4. We use this taxonomy or breakdown of initiatives to organise the remainder of the chapter.

Table 4: A range of initiatives to achieve more efficient and effective outcomes in regard to the use of spectrum in the public sector

Better Information	• Periodic surveys • Improve EFIS data - more complete, more on sharing
Better Institutional Arrangements	• Impose time limits on spectrum grants • Ensure independence of spectrum management authority • Create Member State strategic plans • Create strategic plan for European harmonised spectrum • Plan for hamonised band for broadband emergency services • Assess effectiveness of sharing
Better Management Tools	• Ensure public sector spectrum users know what they are assigned • Explore tools to improve static and dynamic assignment and sharing
Better Technology	• Explore technological options to improve efficiency • Plan to deploy better primary radars
Better Incentive Arrangements	• Require periodic rejustification of assignments • Make allocations as flexible as possible • Find ways to fund refarming of bands • Member States consider, according to their circumstances, whether to implement market-inspired mechanisms (such as AIP, trading)
Better support from related policies	• Procurements should consider the opportunity cost of spectrum • If market-inspired mechanisms are chosen, re-work budget mechanisms accordingly

Table 5 lists our recommendations based on these categories. A more detailed discussion of each recommendation follows later in this chapter. For each Recommendation, Table 5 identifies the *actionee*, the party or parties who should consider the recommendation and implement it if appropriate. The detailed text later in the chapter expands on the specific actions that we regard as appropriate for each actionee. We have taken the liberty of attempting to identify an appropriate actionee even in cases where the European Commission does not have explicit authority to act. In some cases, it is clear that the appropriate actionee is a Member State spectrum management authority; in other cases, however, we have simply indicated that the Member State should address the matter, because the choice of agency within the Member State will depend on specific arrangements in each Member State (which, as we explain in the Annex, vary greatly among the Member States).

Table 5: Summary of Recommendations

Recommendation	**Actionee**
Better information	
R1. Conduct periodic surveys of current spectrum use and evaluate future needs of the public sector.	Member States
R2. Develop guidelines to enhance the consistency of data in the European Frequency Information System (EFIS), and to express shared use more meaningfully in EFIS.	European Commission
Better institutional arrangements	
R3. Where feasible, phase out spectrum "grants" that do not have time limits.	Member States, Spectrum Management Authorities
R4. Ensure appropriate institutional design to enable integrated planning of public and non-public sector use, and impartial and objective decisions between public versus non-public use of specific spectrum bands.	Member States
R5. Develop long term integrated strategic plans for public sector and non-public sector spectrum allocations.	Member States
R6. Develop long term strategic plans for harmonised public sector allocations at European level. Justify with a rigorous impact assessment.	European Commission, supported as appropriate by RSPG, RSC, and/or CEPT
R7. Determine where and how to implement a harmonised band or set of bands for mobile broadband use by emergency services.	European Commission, supported as appropriate by RSC and/or CEPT
R8. Assess the effectiveness of existing arrangements for sharing public sector allocations (with public and non-public sector users). Consider preemptible use.	Member States, including Spectrum Management Authorities
Better management tools	
R9. Ensure that public sector agencies know what spectrum they are using, and ensure that assignments are recorded in centralised databases. Consider developing mechanisms (if they do not already exist) for "licensing" public sector use.	Member States
R10. Undertake ongoing exploration (entailing both technical and policy aspects) and use of automated and/or dynamic tools to improve spectrum assignment and to enhance spectrum sharing for spectrum assigned to the public sector.	Commission and Member States
Better technology	
R11. Ongoing exploration of technological options to improve overall efficiency.	Commission and Member States
R12. Begin coordinated planning for deployment of more spectrum efficient primary radar systems.	Commission, Member States, and other public sector entities (e.g. in the transport sector)

Recommendation	Actionee
Better incentive arrangements	
R13. Ensure that public sector users are subject to a requirement for periodic rejustification of their allocations every few years (with the recognition that this may not be necessary for assignments where the public sector user faces the opportunity cost of spectrum e.g. through participation in an effective secondary market arrangement).	Member States
R14. Evaluate allocations to the public sector to permit as much flexibility of use as is possible.	Spectrum Management Authorities
R15. Consider funding mechanisms for accelerating re-farming of bands allocated to the public sector when appropriate.	Member States
R16. Consider, according to the Member State's circumstances, the potential additional benefits of the use of market-inspired mechanisms in selected bands (as a complement to periodic administrative justification in other bands) to enhance the prospects for socio-economically efficient use of spectrum. If market-inspired mechanisms are implemented in selected bands, ensure that the necessary prerequisites are in place, including: (1) establishing suitable means for determining prices (AIP) where appropriate; (2) putting in place arrangements that enable the public sector agencies to benefit from the economies achieved; (3) giving public agencies ability to participate in a secondary market for spectrum; and (4) providing enough flexibility in assignments to the public sector to make the market arrangements effective.	Member States
Better support from related policies	
R17. Ensure that procurements in the public sector appropriately reflect the opportunity cost associated with spectrum. In particular, ensure that trade-offs between equipment or service quality and spectrum utilisation reflect the realistic opportunity cost of spectrum in evaluating life cycle cost.	Member States
R18. If market mechanisms are applied, revise budgeting processes to enable the public sector agency to benefit from the savings that it achieves.	Member States

The next section of this chapter (Section 5.1) discusses the choice between administrative mechanisms versus market-inspired mechanisms (such as Administrative Incentive Pricing) as a means of ensuring socio-economic efficiencies. In doing so, it seeks to clarify linkages among a number of recommendations. The balance of the chapter then reviews the recommendations in greater detail, beginning with better public availability of information (Section 5.2), and continuing with better institutional arrangements (Section 5.3), better management tools and planning (Section 5.4), better technology (Section 5.5), better incentive arrangements (Section 5.6), and better support from related policies that are not themselves part of the spectrum management process (Section 5.7).

5.1 Administrative mechanisms, market-inspired mechanisms, and linkages among the recommendations

A key driver of our recommendations is the belief that spectrum assignments that are perceived as unbounded in time (and without cost) do not provide incentives to ensure that public sector users pay sufficient attention to using their spectrum assignments in ways that optimise socio-economic efficiency.

Among countries (in Europe and elsewhere) that have tried to address these concerns, the two approaches that hold greatest promise in our view are (1) an administrative approach, based on periodic surveys of audits of spectrum use and a requirement that public sector users periodically plan and justify their requirements for spectrum, and (2) a market- inspired approach, typically based on the simulation of market prices through an Administrative Incentive Pricing, and ideally accompanied by policies that allow public sector entities to participate in spectrum secondary market activities. In Europe, the former approach is exemplified by the Netherlands; the latter, by the United Kingdom. Each approach has much to recommend it – the Netherlands and the UK are to be commended for their leadership and initiative.

We conclude that the administrative approach is a best practice, and its adoption should be encouraged throughout Europe. Given the significant amounts of spectrum (some of which is potentially of high value) used by the public sector, we think that evolving to this form of spectrum management for the public sector is likely to generate net benefits in all Member States. *This is perhaps the most sweeping recommendation in this report.*

We also feel that market-inspired approaches like those used in the UK approach hold great promise, and are likely to lead to greater socio-economic efficiency than administrative means alone. We see merit in expanding the cautious, selective implementation of these market-inspired mechanisms. We have stopped short of a blanket recommendation for three key reasons:

- First, experience to date is limited, so costs and benefits are still uncertain. It is not clear that the incremental gains would exceed costs in all Member States.

- Second, smaller Member States, or those with a less robustly staffed spectrum management authority, might find the complexity of market-inspired mechanisms for the public sector to be daunting, at least initially.

- Third, the effectiveness of these arrangements is heavily dependent on the specific characteristics and circumstances of the Member State, including (1) institutional arrangements, (2) budget processes (see also Section 5.7), and (3) the financial flexibility available to the public sector.

At this point in time, we think that individual Member States should evaluate the potential costs and benefits of market mechanisms for spectrum used by the public sector based on their respective circumstances. Member States that wish to go forward with such an approach should be encouraged. While we have stopped short of recommending overall adoption of market-inspired mechanisms for public sector spectrum today, widespread adoption might nonetheless be appropriate at some future date.

The two approaches are by no means mutually exclusive. Even in Member States that make heavy use of market-inspired mechanisms, it is unlikely that they will be applied all at once, and even in the long run they are unlikely to apply to all bands. Also, while the use of market mechanisms certainly reduces the need for periodic justification, it is not entirely clear that it entirely eliminates it. Thus, we feel that administrative requirements for periodic rejustification are appropriate and should be encouraged in all Member States.

Both approaches imply (1) a move away from the notion that spectrum assignments are made to the public sector for an unlimited duration, (2) the implementation of periodic surveys or audits, and (3) the need to plan for future spectrum use. We think that both of these should be viewed as best practices for all Member States, quite independent of their choices as regards the use or non-use of market-inspired mechanisms.

Finally, we would like to note that there are subtle linkages among the recommendations. The migration away from assignments without time limits, for example, is a key theme. The implementation of licence-like instruments for the public sector is a natural outgrowth of this development. In the case of administrative mechanisms, the licence-like instrument ensures that both the spectrum user and the spectrum management authority are fully cognizant of the assignment; the licence-like instrument also has an expiration date which can help to ensure that the spectrum user must return to the spectrum management authority periodically to reconfirm the assignment. In the case of tradable or leaseable rights, the licence-like instrument defines the rights that can potentially be conveyed.

To re-cap: We think that all Member States should be encouraged to evolve to time-limited assignments to the public sector (where applicable); to periodically survey or audit assignments to the public sector, and to prepare forward-looking plans; and to require periodic justification in bands where it is appropriate. For market-inspired mechanisms for public sector spectrum, we think that Member States that wish to implement them should be encouraged, but we think it would be premature to say that they are appropriate for all Member States.

5.2 Better public availability of information

In each of the following sections, we provide a short list of the recommendations, followed by a more expansive explanation for each recommendation of the **Motivation** for the recommendation, the suggested **Implementation**, and a **Discussion** of the implications of the proposed initiative.

Our recommendations in this area are:

- **Member States:** Conduct periodic surveys of current spectrum use and evaluate future needs of the public sector.
- **Commission:** Develop guidelines to enhance the consistency of data in EFIS, and to more meaningfully express shared used in EFIS.

R1. Conduct periodic surveys of spectrum use by the public sector in order to identify current allocations, assignments and usage, and to project likely future needs.

Motivation: Improving the quality of information available to policymakers and to the public is a necessary first step in any effort to improve spectrum management in the public sector.

Implementation: The Member State would need to undertake this. Surveys in the Netherlands and in the UK provide good models for how to do this. Typically, either the spectrum management authority or a responsible ministry would assemble and rationalise data collected from multiple public sector entities. Experience in the Netherlands and in the UK suggests that the level of effort is significant, but we consider the effort to be warranted in light of the high value of the spectrum that is being managed.

Discussion: Improvements to any aspect of spectrum management in the public sector must begin and end with good data about current and projected future allocations and use. A few Member States, notably including the UK and the Netherlands, have conducted comprehensive surveys of spectrum allocations and usage over the past few years; in many other Member States, comprehensive information about public sector allocations and usage is not available. We call special attention to the importance of a comprehensive program to identify future spectrum needs in advance, since it is apparently not widespread among the Member States. We feel that all Member States should evaluate the quality of the information that they currently have available, both for present and for future needs, and should take appropriate measures to improve it where they identify gaps or shortcomings.

This recommendation bears on the *collection and organisation* of information about current spectrum usage and future needs. The information, in its nature, facilitates the implementation of many other recommendations: (1) the information serves as input to the Member State's strategic plan (Recommendation R5); (2) it provides necessary input for periodic rejustification (R13); and (3) it is also a key input if the Member State chooses to implement any market-inspired mechanisms for public sector spectrum (R16).

R2. Develop guidelines to enhance the consistency of data in EFIS, and to more meaningfully express shared used in EFIS.

Motivation: EFIS is a key central database of spectrum allocation, assignment and usage. More comprehensive and more comparable (across countries) data as regards public sector allocations and usage (including defence in particular) would assist Member State Spectrum Management Authorities, European spectrum planners, and commercial parties in understanding and planning for spectrum usage. More meaningful data as regards spectrum sharing would assist Member State spectrum management authorities, European spectrum planners, and commercial parties in understanding and planning for spectrum usage; moreover, it is an essential first step in assessing the degree to which current sharing arrangements are effective.

Implementation: The Commission's Decision of 16 May 2007 "… on harmonised availability of information regarding spectrum use within the Community, document number C(2007) 2085), 2007/344/EC, already requires Member States to provide annual or semi-annual updates to EFIS. We recommend three changes or clarifications to the text: (1) a clarification that the information called for in Article 3 (with the referenced Annexes) is also required in the case of allocations or assignments that are relevant to the public sector[54]; (2) an acknowledgment that information can be withheld where necessary for reasons of national security; and (3) a clarification as to what information should be provided in the case of bands that are shared. As an alternative, inasmuch as these changes could be viewed as either clarifications or minor revisions to policy that has already been agreed with the European Parliament and the Council, it might be appropriate to initiate these measures either as (1) clarifications from the Commission to the Member States, or (2) as technical implementing measures by means of the committee procedures envisioned in

54 In our view, a requirement for more comprehensive reporting on the allocation and use of spectrum is not in conflict with "the right of Member States to *organise and use* [emphasis added] their radio spectrum for public order and public security purposes and defence." Thus, we see no inconsistency with Article 1(4) of the Radio Spectrum Decision.

the Radio Spectrum Decision (676/2002/EC) of 7 March 2002, and specifically engaging the Radio Spectrum Committee (RSC).

For spectrum sharing, it will first be necessary to specify how to more clearly express the nature and the degree of sharing in a band. This task might appropriately be undertaken by the ERO and/or by the CEPT. Changes to the ERO database might be required to store the expanded information.

Discussion: The level of detail in the data on spectrum allocations that Member States provide to ERO's European Frequency Information System (EFIS) is highly variable, particularly with regard to military spectrum use.[55] It is clear that Member States may have aspects of their spectrum allocations that they do not wish to make public for various reasons, including national security, but the degree of variation from one Member State to the next seems to us to be greater than that which is desirable or necessary.[56] There could be a role, perhaps for the RSPG and/or ERO, in drafting guidelines that enhance consistency in the level of detail provided by Member States.

Current information in EFIS about spectrum sharing is of limited value. Knowing that a spectrum band is nominally shared conveys little information in and of itself. A policymaker generally also needs to know (1) how is the band shared (i.e. in which dimension), and (2) how effective is the sharing in practice. The latter of these is much more difficult to determine and to express than the former. Again, there could be a role, perhaps for the CEPT and/or ERO, in drafting guidelines that enhance the information about shared allocations that is provided by Member States.

The Commission Decision 2007/344/EC recognises the need to protect individual privacy and to respect business confidentiality; however, there does not appear to be any mention of state secrets or national security. One could conceivably address this by means of EFIS access controls; however, we assume that some spectrum management data is too sensitive to provide to EFIS in the first place. Language needs to be carefully crafted to permit data to be withheld from EFIS where necessary and appropriate, but without creating a needlessly broad exclusion.

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55 In some cases, no information on military use is provided at all; in others, there is no indication of the type of use (e.g. aeronautical, fixed, land mobile). This information is essential for assessing the potential for sharing the spectrum with other public sector or commercial uses.

56 See Table 2.

5.3 Better institutional arrangements and planning

Our recommendations are:

- **Member States, Spectrum Management Authorities:** Where feasible, phase out spectrum "grants" that do not have time limits.

Institutional arrangements

- **Member States:** Ensure appropriate institutional design to enable integrated planning of public and non-public sector use, and impartial and objective decisions between public versus non-public use of specific spectrum bands.

Planning:

- **Member States:** Develop long term integrated strategic plans for public sector and non-public sector spectrum allocations.
- **European Commission, supported as appropriate by RSPG, RSC, and/or CEPT:** Develop long term strategic plans for harmonised public sector allocations at European level. Justify with a rigorous impact assessment.

Specific initiatives:

- **European Commission, supported as appropriate by RSC and/or CEPT:** Determine where and how to implement a harmonised band or set of bands for mobile broadband use by emergency services.
- **Member States, including Spectrum Management Authorities:** Assess the effectiveness of existing arrangements for sharing public sector allocations (with public and non-public sector users). Consider preemptible use.

R3. Where feasible, phase out spectrum "grants" that do not have time limits.

Motivation: As long as grants are unlimited in duration, it will be difficult to manage them so as to foster greater socio-economic efficiency. A time limit facilitates any periodic rejustification process.

The interaction with market-inspired mechanisms, in Member States that choose to implement them, is more complex. The implementation of Administrative Incentive Pricing (AIP) clearly associates spectrum rights with a specific duration; on the other hand, if a Member State chooses to implement spectrum trading by public sector spectrum users in a particular band, economic incentives might obviate the need to limit the duration of the assignment. (If an assignment were no longer needed, it would tend to be traded to an organisation that values it more.)

Implementation: For government agencies, this is generally a matter for the Member States. Existing rights of use might be provided by some ministry, or by the spectrum management authority. In some Member States, current arrangements may be informal.

Discussion: A possible mechanism to achieve this would be to implement a licence-like instrument, which is a separate mechanism (see Recommendation R10 in Section 5.4, dealing with Better Management Tools).

The degree to which this recommendation applicable to bands that are globally harmonised (for example, aeronautical or maritime spectrum that is allocated by the ITU) needs some reflection. In general, the efficiency of these bands cannot be meaningfully addressed at the level of the individual Member State.

R4. Ensure appropriate institutional design to enable impartial and objective decisions between public versus non-public use (including shared use) of specific spectrum bands.

Motivation: To achieve the appropriate balance between public and non-public sector use of spectrum, with decisions informed by analysis of the costs and benefits of competing uses of the spectrum.

Implementation: This is a matter for the Member States. Given that spectrum management institutional arrangements differ greatly from one Member State to the next, the means of achieving this objective will also tend to differ greatly from one Member State to the next.

Discussion: Where individual bands are to be allocated to public or non-public sector use, it seems to us to be best practice that an organisation do this that has appropriate responsibilities for both, and that is not so constituted as to be motivated to inappropriately favour one form of use over the other. This implies a need for careful institutional design. In countries where the organisational distance between public sector and non-public sector spectrum management is great, it tends to be more difficult to achieve economically efficient allocations, and also more difficult to achieve spectrum sharing between the public and the non-public sector.[57]

This could be viewed as providing a degree of regulatory independence to the Member State Spectrum Management Authority (SMA) similar to that which the Commission has advocated (in its November 2008 proposed revisions to the European Regulatory Framework for electronic communications) for the National Regulatory Authority.

R5. Develop long term integrated strategic plans for public sector spectrum allocations at Member State level. Identify future needs, and also future lack of need, at the Member State level.

Motivation: A long term strategic view enables more coherent management, and potentially a better balance between public sector and non-public sector allocations.

Implementation: This is a matter for the Member States. The spectrum survey identified in Recommendation R1 in Section 5.2 above will tend to be a key input to this process. As noted in the previous recommendation, it is important that this activity be undertaken by a public agency that both public and non-public sector spectrum users respect, and that they trust to make fair judgments.

It is important that this planning process be sufficiently inclusive, and that it facilitate appropriate levels of interaction between the military and civilian establishments, including emergency services.

Once the plan has been completed, it should be posted to the ERO web site, consistent with Article 3(b) of the Commission's Decision 2007/344/EC on harmonised availability of information regarding spectrum use.[58]

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57 There are, for instance, indications that this is the case in the United States.

58 The Article calls for "national spectrum policy and strategy in the form of a report" to be posted to the ERO web site if such a report is available.

Discussion: We see scope for strategic planning in regard to spectrum needs, especially in regard to the balance between public and non-public sector spectrum allocations, not only at the European level but also at the Member State level. Policymakers tend to be confronted with large numbers of detailed decisions to be made about individual bands, but only a few Member States step back to take an overall view. In our view, Member States that take an overall, strategic view of their management of their public sector spectrum are far better positioned to manage their spectrum effectively than those that do not (and that thus must manage reactively to needs as they emerge). Having said this, we would add that this strategic review should be undertaken by an organisation that can take a balanced view toward public and non-public sector allocations, that has authority over both and can take an integrated view of both, and that is not motivated to inappropriately favour one over the other (see the previous recommendation).

The planning process should place particular emphasis on defence. Civil and military requirements should be examined together, particularly for new applications. Also, the public safety sector might profitably work more closely with defence to gain access to their spectrum during public emergencies (e.g. terrorist attacks), which might offset the need for more spectrum from elsewhere.

R6. Develop long term strategic plans for harmonised allocations for the public sector at European level. Where this planning process identifies bands that might benefit from European harmonisation, perform a rigorous impact assessment.[59] This is particularly important when larger blocks of spectrum are expected to become available (as is the case with the Digital Dividend).

Motivation: A long term strategic view enables more coherent management, and provides guidance to the Member States and to private sector and public sector spectrum users. Any occasion when large blocks of spectrum are expected to be freed provides an unusual opportunity to implement spectrum bands that are harmonised at the European level, but this is just a specific example of the more general principle.

Implementation: We view this as an activity for the Commission, possibly with input from the various advisory bodies available to the Commission (including the CEPT ECC, the ERO, and the RSPG). The Commission already performs

59 Harmonisation of spectrum bands can be beneficial, but it is not costless. There is an inherent tension, but not necessarily an incompatibility, between band harmonisation and flexibility. "Costs and benefits need to be assessed in each case." CEPT Electronic Communications Committee (ECC), *Enhancing Harmonisation and Introducing Flexibility in the Spectrum Regulatory Framework*, ECC Report 80, March 2006.

considerable spectrum planning, but much of it tends to be case-by-case basis rather than on an overall strategic basis.

Once again, it is important this planning process be sufficiently inclusive, and that it facilitate appropriate levels of interaction between the military and civilian establishments, including emergency services. This likely involves improved communication mechanisms, both at European level and at Member State level. As an example of the former, it is probably appropriate that the EDA play a more active liaison role with the Commission in regard to spectrum policy, which could perhaps include granting the EDA observer status in the RSPG.[60] At Member State level, it may be appropriate to strengthen interaction between the civilians on the Radio Spectrum Committee (RSC) and their military and emergency services counterparts so as to ensure that they receive timely notification of any Draft Decision that could affect the existing use of a frequency band and to take appropriate action.

The Commission already has authority to "facilitate policy making with regard to the strategic planning and harmonisation of the use of radio spectrum in the Community" and to report on the results, in conjunction with committee procedures, under the Radio Spectrum Decision (676/2002/EC).

Discussion: We see continued scope for strategic planning in regard to spectrum needs at the European level. This is consistent with the European Commission's stated direction in the recent review of the European regulatory framework. The Commission has a key role to play in achieving harmonised European bands where needed, and can also coordinate and advocate European positions before international bodies such as the ITU.[61] Given the long time frames associated with clearing previously non-harmonised bands, an overall, strategic view of the management of public sector spectrum is crucial.

Harmonised bands are not unique to the public sector. There are other reasons to harmonise, such as for example in order to support inexpensive licence-exempt devices. Nonetheless, harmonisation is a particularly common requirement in portions of the public sector due to the need to operate transparently across national boundaries.

Harmonisation is most likely to be appropriate where some combination of the following hold: (1) cross-border interoperability is necessary; (2) economies of scale, e.g. in equipment manufacturing, are especially important; (3) equipment must be portable across national borders: or (4) the prospective user community is fragmented, and thus unable to aggregate its demand (akin to an economic

60 The Commission already has observer status on the EDA's Radio Spectrum project team.
61 The Commission can, notably, issue mandates to the CEPT.

public goods problem). For reasons noted below, harmonisation should be used with care, with appropriate attention to costs and benefits.

Concrete examples where harmonised bands might in the future be appropriate include:

- A harmonised band for LAN-like use for public safety (see Recommendation R7 later in this section); and
- Harmonised spectrum allocations for Unmanned Air Vehicles (UAV), both for civilian and military use. Note that this item will be on the agenda of the WRC-11.

Spectrum harmonisation in Europe takes place at many different levels: the ITU level (especially through the WRC), in NATO, and at the level of the European Union.

The effectiveness of strategic planning and of administrative judgment clearly depends on the quality of information available to the decision maker; thus, the ability to implement this Recommendation is closely linked to successful implementation of Recommendations R1 and R2.

Allocation of a band to harmonised use should be done with care, since the allocation will tend to be made without the benefit of a market determination and thus without assurance that the value is the intended use is truly such as to warrant the allocation. These allocations are effectively taken out of play for market-inspired mechanisms such as auctions that would otherwise help to ensure economically efficient use. If spectrum is to be reserved for public sector spectrum use on a harmonised basis across Europe, then this should be justified by means of an impact analysis.

Within the European Union, it is very difficult to locate new spectrum that is suitable for harmonised use;[62] at the same time, new applications and new demands are emerging, especially in regard to emergency services (where for example concerns with natural disasters, terrorism, and routine cross-border activities are creating new demands for far greater interoperability than was previously the case). All of this implies that the Commission needs to be particularly alert to opportunities for harmonised allocations whenever a consistent block of spectrum becomes available, as for example is about to be the case as a result of the Digital Dividend.

62 WAPECS is an example where harmonisation is being achieved Member State by Member State.

R7. The Commission should evaluate possible implementation of a harmonised band or set of bands for harmonised broadband use by emergency services.

Motivation: Numerous stakeholders expressed a strong need for harmonised spectrum for broadband emergency services use. This is driven in part by a need to share video, and in part by the need for full interoperability among different services and across borders. In most instances, we have refrained from making such specific recommendations; however, in this case, stakeholder feedback was particularly clear and insistent.

Implementation: The Commission should first seek, through whatever means, to get stakeholders to rigorously identify their requirements.

In principle, this could be addressed by means of the strategic planning process advocated in Recommendation R6 in Section 5.3. This would imply the identification, possibly with input from the CEPT, of a suitable band. Our initial judgment is that a harmonised band is likely to be warranted, but consistent with good process we recommend that costs and benefits be carefully assessed.

Given, however, that the strategic planning process does not yet exist, it may be appropriate to deal with this need on a more accelerated *ad hoc* basis.

Discussion: This was a recurrent theme in numerous interviews and in the public workshop of 1 April 2008. Some have suggested satisfying the demand out of Digital Dividend spectrum.[63]

R8. Reassess the effectiveness of spectrum sharing arrangements for spectrum assigned to the public sector.

Motivation: Implementation of more effective spectrum sharing could enhance economic efficiency. Current arrangements should be reviewed to consider not only whether bands are formally available for sharing, but also the forms of sharing that are permitted, and also with an eye to determining the degree to which sharing is actually taking place. Publicly available information today is insufficient to determine how much sharing is taking place, and how effective it is.

Implementation: This recommendation should be put in place *after* the recommendation in Recommendation R2 in Section 5.2 to provide better

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63 See Carter, Kenneth R. and Val Jervis, *Safety First: Reinvesting the Digital Dividend in Safeguarding Citizens*, White Paper by wik-Consult GmbH and Aegis Systems, available at: http://www.public-safety-first.eu/White%20paper%20Executive%20Report_final.pdf (30 April 2008).

information on sharing in EFIS has been in effect for long enough to produce data worth analysing. At that point, the Commission should initiate studies by the RSPG, or by an independent consultant, or both.

This analysis might if appropriate be followed by a planning process that would determine what further steps (if any) should be taken to ensure an adequate level of sharing.

Discussion: Many Member States allow sharing of public sector spectrum, but it is difficult to determine how effective this sharing really is. Some Member States provide for extensive sharing within the public sector, but only for limited sharing between certain public sector users (e.g. defence) and the non-public sector. Some routinely share public sector spectrum for major public events (sporting events, concerts).[64] Many share military and civilian spectrum in sectors such as maritime and aeronautical. Despite all of this, it is not clear that public sector spectrum users are motivated to ensure that sharing is as effective as it should be – for example, they do not appear to be motivated to use joint planning tools used to facilitate socio-economically efficient spectrum use. We believe that a first step should be to develop a better understanding of sharing with the public sector, as we have noted in Sections 4.2 and 5.2. With better data in hand, the policy question of the effectiveness of sharing with the public sector should be revisited.

5.4 Better management tools

Our recommendations in regard to improvements in management tools and mechanisms are:

- **Member States:** Ensure that public sector agencies know what spectrum they are using, and ensure that assignments are recorded in centralised databases. Consider developing mechanisms (if they do not already exist) for "licensing" public sector use.

- **Commission and Member States:** Undertake ongoing exploration (entailing both technical and policy aspects) and use of automated and/or dynamic tools to improve spectrum assignment and to enhance spectrum sharing for spectrum assigned to the public sector.

64 Support for special events is referred to as Programme Making and Special Events (PMSE).

R9. Ensure that public sector agencies know what spectrum they are using, and ensure that assignments are recorded in centralised databases. Consider developing mechanisms (if they do not already exist) for "licensing" public sector use.

Motivation: The objective here is to empower public sector spectrum users to better manage their spectrum holdings, and enable spectrum management authorities to manage the overall pool of public sector more effectively. This might seem obvious, but experience in a number of countries suggests that it should not be taken for granted. Experience (especially with the spectrum audit in the Netherlands) has demonstrated that public sector spectrum users are not necessarily aware of all of the spectrum that has been assigned to them, and that they may not appreciate the economic value of that spectrum. This is less of a problem with non-public sector spectrum, which in most cases can be tracked easily by the Member States spectrum management authority through existing databases and/or licensing systems. We propose that comparable controls be implemented for public sector spectrum, to the extent that they do not already exist.

Implementation: This recommendation would need to be implemented by the Member States. In many cases, it would be appropriate for the spectrum management authority to take responsibility for recording and licensing assignments to the public sector; however, given the wide range of variation among the Member States, it is likely that implementations would vary from one Member State to another.

Discussion: Information/data on actual spectrum use by the public sector (i.e. assignments) is not always well documented or even well understood by the user organisation. Sometimes this is because assignments are not formalised in licences and/or there is no centralised database in which assignments are recorded either by the user or any other organisation. This lack of transparency in current use means the spectrum occupancy is unlikely to be planned optimally from a technical perspective, under-use will occur and not be detected, unexpected interference may occur and co-ordination with neighbouring public/non-public sector users may be difficult to achieve efficiently.

Current arrangements are likely to be very diverse among Member States, and even between different spectrum users (for example, defence versus aeronautical) within the public sector.

The creation of a licence-like instrument would be worthwhile as a management tool, even if none of our other recommendations were implemented. It clearly facilitates the periodic spectrum surveys that we have advocated (see Recommendation R1 in Section 5.2) and the strategic planning process at

Member State level (see Recommendation R5 in Section 5.3). In Member States that implement our recommendation to require periodic administrative rejustification of spectrum assignments to the public sector, the licence-like instrument helps to enforce the notion that the assignment is for a bounded time (see Recommendation R3 in Section 5.3) and that it needs to be renewed. For Member States that choose to implement market-inspired mechanisms such as Administrative Incentive Pricing (AIP) (see Recommendation R16 in Section 5.6), the licence-like instrument again serves to emphasise the time-bounded nature of the assignment. For Member States that also seek to implement tradable rights as the UK has done, a licence-like instrument is crucial in defining the rights that the spectrum holder has (and is therefore able to trade if desired). Again, we emphasise that a management tool similar to a license has many potential uses, irrespective of whether a particular Member State chooses to implement market-inspired mechanisms for public sector spectrum.

R10. Undertake ongoing exploration (entailing both technical and policy aspects) and use of automated and/or dynamic tools to improve spectrum assignment and to enhance spectrum sharing for spectrum assigned to the public sector.

Motivation: A number of techniques are evolving for rapidly *reassigning* and *sharing* spectrum. Some of these are essentially database management tools that operate in real time or near-real time; others are dynamic sharing approaches. Automated or semi-automated allocation mechanisms could increase the effective carrying capacity of spectrum and reduce administrative costs. Shared use of spectrum could also increase the effective capacity of the spectrum in a different way.

Implementation: Implementation has many aspects. Database management tools for automated or semi-automated assignment are in general deployable today, but applications to use them need to be thought through.

Sharing techniques such as Cognitive Radio are still novel, and would benefit from continued research funding at the European level and possibly also at the Member State level.

Discussion: The automated assignment tools in use in the aeronautical sector (SAFIRE) seem to us to represent a best practice, although it is not immediately clear the degree to which they might be applicable to other public sector applications. The semi-automated assignment of spectrum in the 70-80-90 GHz bands in the US represents another example of assignment automation.

The use of software defined radio (SDR) and cognitive radio (CR) could provide superior solutions to sharing, offering the benefits of DFS while addressing some

of the limitations of DFS. For example, licence-exempt equipment could check on power-up whether it has the latest firmware, and download a current version if not. The newly downloaded firmware would be aware of any new frequency limitations, for example to protect new types of radar system. In this way, licence-exempt equipment would not transmit on frequencies that are reallocated to sensitive public sector applications in the future.

The use of automated and/or dynamic tools for planning and for sharing (especially between the public sector and the non-public sector) is a promising area for continued study.

5.5 Better technology

In regard to technological enhancements, we recommend the following:

- **Commission and Member States:** Undertake ongoing exploration of technological options to improve overall efficiency.
- **Commission, Member States, and other public sector entities (e.g. in the transport sector):** Begin coordinated planning for deployment of more spectrum efficient primary radar systems.

See also our recommendation for continued exploration and use of automated and/or dynamic tools to improve spectrum assignment and to enhance spectrum sharing for spectrum assigned to the public sector.

R11. Undertake ongoing exploration of technological options to improve overall efficiency.

Motivation: New technologies can enable more efficient exploitation of the radio spectrum, thus effectively expanding capacity.

Implementation: This is initially a research activity that should be promoted through the Commission's research funding capabilities, and through those of the Member States. This could appropriately become a priority research topic for the Commission's Framework Programme 7 (FP7).

Once the technology is sufficiently mature, deployment of cost-effective technologies should be planned and initiated. In most cases, the benefits are obvious to the spectrum user, and deployment will commence without further intervention. In other cases, the benefits might primarily go to other spectrum users, not to the spectrum user that must make the investments (akin to an

economic "public goods" problem). In still others, European coordination may be required. Intervention at Member State or European level may thus be appropriate in some circumstances, but case-by-case assessment is necessary.

Discussion: Just as the transition to digital broadcasting is generating benefits in the non-public sector, ongoing technological advances can produce benefits in the public sector.

For example, progressive improvements in radar technology could generate significant benefits in terms of reduced spectrum needs. Achieving these benefits in the case of radar would require funding, and might require a significant amount of international coordination. Re-planning of the primary radar band (2.7 -2.9 GHz) and possibly others could for example be necessary to take account of improved out-of-band emissions from solid state radars.

R12. Begin coordinated planning for deployment of more spectrum efficient primary radar systems.

Motivation: Radar represents one of the largest users of spectrum for the public sector. The full deployment of improved technology for primary radar could result in delivery of the same capabilities with perhaps 30% less spectrum.

Implementation: A number of initiatives at Member State level are already under way. Given the coordination required between military and civilian radar, there would appear to be scope for coordination at the Member State level, and probably also at European level. In the case of maritime radar, primary radar is installed on many vessels, thus limiting the scope for upgrading on a country by country basis.

Discussion: See Section 3.3.

5.6 Better incentive arrangements

In our view, providing incentives to the public sector to help ensure use that is not only effective in achieving its mission, but also socio-economically efficient, *is a key area for improvements*. We recommend:

- **Member States:** Ensure that public sector users are subject to a requirement for periodic rejustification of their allocations every few years (with the recognition that this may not be necessary for assignments where the public sector user faces the opportunity cost of spectrum e.g. through participation in an effective secondary market arrangement).

- **Spectrum Management Authorities:** Evaluate allocations to the public sector to permit as much flexibility of use as is possible.

- **Member States:** Consider funding mechanisms for accelerating re-farming of bands allocated to the public sector when appropriate.

- **Member States:** Consider, according to the Member State's circumstances, the potential additional benefits of the use of market-inspired mechanisms in selected bands (as a complement to periodic administrative justification in other bands) to enhance the prospects for socio-economically efficient use of spectrum. If market-inspired mechanisms are implemented in selected bands, ensure that the necessary prerequisites are in place, including:

    - establishing suitable means for determining prices (AIP) where appropriate;

    - putting in place arrangements that enable the public sector agencies to benefit from the economies achieved;

    - giving public agencies ability to participate in a secondary market for spectrum; and

    - providing enough flexibility in assignments to the public sector to make the market arrangements effective.

R13. Ensure that public sector users are subject to a requirement for periodic rejustification of their allocations every few years (with the recognition that this may not be necessary for assignments where the public sector user faces the opportunity cost of spectrum e.g. through participation in an effective secondary market arrangement).

Motivation: Periodic review should be used where appropriate in order to enhance the likelihood that spectrum that is no longer needed for public sector use can be made available to higher value public or private sector use. (Periodic review may not be necessary for spectrum that is subject to market-inspired mechanisms such as Administrative Incentive Pricing and/or trading in a secondary market.)

Implementation: Member States would need to carry out such a review. To be credible and effective, it should be undertaken by a public agency that is reasonably independent from Member State public sector spectrum users (see our recommendation to this effect in Section 5.3).

Discussion: For spectrum allocations to be effective and efficient, it is clear that they must be subject to periodic review (whether administrative or market-inspired). A system of indefinite allocations without review is not conducive to long term efficiency.

The periodic survey of public sector spectrum assignments (Recommendation R1 in Section 5.2), the phasing out of rights of indefinite duration (Recommendation R3 in Section 5.3), and the implementation of licence-like instruments (Recommendation R9 in Section 5.4) all contribute positively to the ability of Member States to manage and monitor public sector use of spectrum and thus to conduct this periodic rejustification.

Market-inspired mechanisms (including Administrative Incentive Pricing, or AIP) could play an important positive role in determining the appropriate balance between public sector and non-public sector usage, but they will not be relevant to all Member States, nor to all bands even in the Member States that implement them. This implies that some degree of administrative controls and judgment is likely to continue to be appropriate in all Member States.

R14. Evaluate all allocations to public sector users in order to permit as much flexibility of use as is possible consistent with the use of the band and with the risk of interference in adjacent bands or adjacent geographic areas.

Motivation: Enhanced flexibility for public spectrum allocations could enable more sharing of spectrum, and can also serve as an important complement to the implementation of market-inspired mechanisms if they are desired. This is consistent with notions of technological and service neutrality.

Implementation: As Member States assign new bands to public sector users, they should impose as few restrictions as possible. For existing bands, as Member States conduct the survey advocated in Recommendation R1 in Section 5.2, they could consider whether usage is more restricted than is necessary (for example, to minimise the risk of harmful interference in adjacent bands or geographies).

Discussion: Public sector users typically already enjoy substantial flexibility as regards the use of their assigned spectrum; however, there is an argument that spectrum allocations for public sector users should be as flexible as possible, consistent with avoidance of harmful interference, just as they should be for non-public sector users. In Member States that implement market mechanisms for public sector spectrum, this is particularly important, inasmuch as leasing or trading will tend to be of less effective in the absence of flexibility. Flexibility is also essential to certain forms of spectrum sharing.

R15. Consider funding mechanisms for re-farming that might accelerate the clearing of bands when appropriate.

Motivation: Explicit funding for refarming could enable bands to be more rapidly cleared, and thus reallocated to uses with greater socio-economic value. At present, public sector use inhibits private sector use of some frequency bands (e.g. the 2.6 GHz band) that have been harmonised at a European level.

Implementation: Member States would need to enable funding from some source other than the normal operating budget of the public sector user that is vacating the spectrum. Refarming might be funded from some central budget at Member State level, or it might be funded out of the proceeds of auctioning off (or trading or leasing) the spectrum. There are a number of obstacles to funding in this way in most Member States today. In some cases, this might require legislative changes at Member State level.

Discussion: Maintaining the appropriate balance between public sector and private sector usage over time necessarily implies that some bands might migrate from public sector to non-public sector use, or vice versa.[65] Refarming poses a number of unique challenges. Transition of a frequency band from one mode of use to another (for example, from military use to private sector use) often implies that previous equipment becomes obsolete. If a public sector user has to fund the migration out of ongoing operating revenues, they may be motivated to retain spectrum allocations far longer than would be economically efficient. Conversely, if all of the costs associated with migration were ignored (for instance, assumed by the government out of general revenues), spectrum allocations might "churn" inefficiently.

Our sense is that the approach used in GSM bands in some countries – where commercial users effectively paid the military to vacate the bands – was a good practice. Whether it is a model that can be generalised to all spectrum bands in all Member States is unclear, in part because there may not always be a user to pay for migration costs, in which case the central government may need to fund the transition.

Some public sector entities are in reality private firms (for example, in the aeronautical or maritime sectors). Where the public sector entity vacating a band is a private body, it is particularly important to ensure that re-farming payments do not exceed the cost of vacating the band (so as to avoid an inappropriate subsidy to the private firm).

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65 Bands could also migrate from non-public sector to public sector use, but this has rarely been the case in recent years.

R16. Consider, according to the Member State's circumstances, the potential additional benefits of the use of market-inspired mechanisms in selected bands (as a complement to administrative justification in other bands) to enhance the prospects for economically efficient use of spectrum. Perform an impact assessment if appropriate. For Member States that choose to implement market-inspired mechanisms in selected bands, ensure that necessary prerequisites are in place, including (1) establishing suitable means for determining prices (AIP) where appropriate, (2) putting in place arrangements that enable the public sector agencies to meaningfully benefit from the economies achieved, (3) ability for the relevant public agencies to participate in a secondary market for spectrum, and (4) providing enough flexibility in assignments to the public sector to make the market arrangements effective.

Motivation: Few public sector users face financial incentives to use spectrum more efficiently. The lack of financial incentives means there is little cost to delaying actions that may improve spectral efficiency, and also little cost to hoarding and/or not sharing spectrum. In addition, the potential benefit to investing in more economically efficient technologies and equipment is less than would otherwise be the case. The adoption of market-inspired mechanisms into the management of public sector spectrum potentially addresses all of these problems.

Implementation: This is a Member State activity, for Member States that choose to implement market-inspired mechanisms. (Not all possible mechanisms need to be implemented, and it is unlikely that any Member State would implement market-inspired mechanisms in all public sector bands.) As noted, a great many preconditions need to be established in order to make the implementation of market-inspired mechanisms fully effective for public sector spectrum.

The RSPG should be actively engaged in this process so as to ensure that best practices are shared among the Member States and at European level.

Discussion: We stopped short of making this a general across-the-board recommendation, because we felt that it was too early to rigorously establish the balance between costs and benefits of this policy (see Section 5.1).

For those Member States that implement market mechanisms for portions of the public sector as part of a comprehensive package that enables the public sector actor to benefit from cost savings and/or from revenues obtained from leasing or trading spectrum, one would expect to achieve a more economically efficient balance of public sector and non-public sector spectrum allocations. Experience in the UK provides some preliminary support for this view.

Market mechanisms should be phased in gradually (phased approach) and on a case by-case-basis, taking into account harmonisation issues, interference issues, and economic considerations specific to the intended application. For an example of a relevant economic consideration, some public sector users are diffuse (e.g. emergency services) such that it may be impractical to aggregate demand so as to pay for the spectrum; thus, some bands are likely to remain subject to administrative controls rather than market-inspired mechanisms for many years to come.

Market mechanisms can be an effective tool for improving the efficiency and effectiveness of spectrum usage, but only when implemented as part of a comprehensive package of spectrum management practices. With market mechanisms, public sector users would tend to be motivated to acquire only spectrum that they need, to use it with appropriate economy, and to release it when no longer needed. They would also tend to be motivated to make appropriate trade-offs – for example, in cases where investment in equipment of better quality would permit the use of less spectrum. For all of this to be effective, many conditions must be met, including: (1) Administrative Incentive Prices (AIP) must correspond well enough to market prices,[66] (2) public sector agencies must have the ability to use money saved and/or revenues from trades or leases for other agency purposes (see (Recommendation R18 in Section 5.7), and (3) public sector agencies should have the ability to trade and/or lease spectrum, including to the private sector, so that they are confronted daily with the opportunity cost of holding spectrum.

5.7 Better support from related policies

- **Member States**: Ensure that procurements in the public sector appropriately reflect the opportunity cost associated with spectrum. In particular, ensure that trade-offs between equipment or service quality and spectrum utilisation reflect the realistic opportunity cost of spectrum in evaluating life cycle cost.

- **Member States:** If market mechanisms are applied, revise budgeting processes to enable the public sector agency to benefit from the savings that it achieves.

66 In the absence of an auction, setting AIP prices is by no means trivial. See Section 4.5.3.2.

R17. Ensure that procurements in the public sector appropriately reflect the opportunity cost associated with spectrum. In particular, ensure that trade-offs between equipment or service quality and spectrum utilisation reflect the realistic opportunity cost of spectrum in evaluating life cycle cost.

Motivation: To the extent that public sector agencies recognise that spectrum has economic value, whether they themselves pay for it or not, they would tend to make procurement decisions that have greater socio-economic efficiency.

Implementation: For Member States that implement market-inspired mechanisms, and in bands where they are relevant, this recommendation is more-or-less automatically fulfilled.

In most or all other cases, explicitly recognising the opportunity cost associated with spectrum is likely to require changes to Member State procurement arrangements in the public sector.

There might also be a need to re-examine European procurement rules, inasmuch as they require that public procurements be awarded solely on the basis of objective economic or technical criteria (either the lowest price or the economically most advantageous tender overall); it not clear whether these rules might limit the ability to recognise a "shadow price" for spectrum.[67]

Discussion: Procurement decisions made by public sector users rarely include consideration of the opportunity cost of spectrum used. This implies a risk that public sector spectrum users might employ spectrally inefficient solutions, and that public sector spectrum users may invest insufficient effort in improving spectral efficiency and/or may invest insufficient capital for equipment procurement.

For procurements to explicitly reflect the opportunity cost associated with the spectrum required should also help to mitigate the risk that the procurements pay insufficient attention to the possibility of using commercial off-the-shelf (COTS) solutions. There are many public sector systems for which COTS solutions would not provide appropriate quality of service or robustness, but the acquiring entity should not automatically assume this to be the case.

67 We view this question as being well beyond the scope of the current study.

R18. If market mechanisms are applied, revise budgeting processes to enable the public sector agency to benefit from the savings that it achieves.

Motivation: For market mechanisms to be effective in the public sector, the public sector spectrum users would need to be able to benefit from savings due to the use of less spectrum, or from revenue due to the lease or trade of spectrum that is no longer needed. Conversely, there should be some disincentive to the public sector spectrum user acquiring more spectrum than it strictly needs.

Implementation: To a significant degree, this has to be viewed as a research question. Even the UK, where market-inspired mechanisms for the public sector are most advanced, does not claim to have a complete and comprehensive solution. Either the Commission, or the Member States that have implemented or that hope to implement market mechanisms in the public sector, may wish to use the tools available to them to stimulate relevant research.

For government agencies, including defence and most public safety organisations, any implementation would appear to be in the hands of the Member States. For the aeronautical and maritime sectors, however, many of the relevant players are subject to normal incentives to avoid needless cost.

Discussion: Market mechanisms are effective in the non-public sector because commercial firms (and also non-profit organisations) are naturally motivated to minimise costs.

In the public sector, however, and especially for government agencies, arrangements may work differently.[68] If a Ministry of Defence, for example, were able to save money by using less spectrum (and therefore reducing the Administrative Incentive Payments (AIP) that it must make), there might be restrictions on its ability to re-apply the savings to other purchases (personnel, armaments, whatever).

Analogously, if a Ministry of Defence (to carry the same example further) were to lease spectrum to a commercial third party, it would not necessarily be permitted to reinvest the proceeds in other assets that it needs. For that matter, it is not

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68 Cf. Adele Morris and Martin Cave (2005): "Getting the best out of public spectrum": "[T]he long run effect of administrative pricing depends greatly on how well the price signals survive the appropriations process. If each agency automatically receives budget authority to cover its spectrum user fees (and that funding is not fungible), then no new efficiency incentives are created. … On the other hand, if appropriators simply cut the budget of agencies that save on spectrum costs, again the incentives are totally undermined. A budget system that on net makes agencies indifferent to the spectrum price will not change incentives. In the UK, procedures have been developed based upon multi-year budgeting which introduce some level of incentives to save costs of all kinds. … Note the similarity with limited period price caps."

altogether clear that the public interest would be well served if an unexpected windfall of spectrum revenue were reinvested in other defence assets.

Finally, if the agency were to give up spectrum, and benefit from doing so, what happens if it later finds that it needs more spectrum after all? Presumably, national authorities will not deny a necessary spectrum assignment; nonetheless, it could be problematic for a public sector spectrum user to benefit from giving up spectrum that really was needed after all.

All of these problems would appear to be solvable, but as of today they are not solved.