



Independent Audit of SPECTRUM HOLDINGS



DECEMBER 2005

by Professor Martin Cave for Her Majesty's Treasury



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An Independent Audit for Her Majesty's Treasury

December 2005

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Foreword

In the Pre Budget report of 2004, the Chancellor announced my appointment to undertake a review of major spectrum holdings, aimed at releasing the maximum amount of spectrum to the market and increasing opportunities for the development of innovative new services. I now deliver my report.

My focus has been on public sector spectrum holdings, which account for about half of the spectrum in the Audit's remit and which are subject to different incentives from spectrum held by commercial users. Analysis of future demand suggests that it is quite likely that total demand for public and private sector spectrum will exceed available supply: this will make it necessary for both sets of users to make more efficient use of spectrum.

My report falls into two parts. The Audit team have analysed selected major spectrum holdings in the defence and aeronautical fields, identifying areas where more or less immediate reallocation of spectrum is feasible, and areas where something can be done in the medium term.

Secondly, ways have been identified of imposing continuing economic pressure on public sector users to economise in the future. These involve in particular enhanced incentives on public sector bodies to sell or lease unneeded spectrum, the extension of the system of charging administered incentive prices for spectrum, and further development and use of methods of spectrum sharing.

I believe that a combination of these two approaches, one involving challenge to existing users, the other the sharpening of incentives, are capable of releasing spectrum as required. But I also recommend a review of progress in five years, as the success of the spectrum management framework set out here depends to a large extent on how the spectrum market – still in its early stages - develops.

I am pleased with the level of engagement we have received from core and wider stakeholders, and have found the contributions to our consultations, meetings and seminar invaluable.

I am grateful to the Audit team – the Core Secretariat of Helen Watson and Sam Whittaker, and the wider team - for very impressive work over the past months, in a complex area and subject to tight deadlines. The names of the team are listed at the front of the report.

A handwritten signature in black ink that reads "Mark Carl". The signature is written in a cursive, slightly slanted style.

Executive summary

Overview

The conclusions of this Independent Audit of Spectrum Holdings cover two main areas. Firstly, specific bands are analysed. This detailed audit covers just over twenty key bands in the Audit's range of study (up to 15 GHz), making a judgment on the likely scope for releasing these for alternative use or admitting new sharers.

Secondly, the overarching public sector spectrum management regime is examined and an alternative framework set out. This framework can be summarised under four themes: the extension of market mechanisms to the public sector; a more comprehensive approach to the application of Administered Incentive Pricing (AIP) as a tool for incentivising more effective spectrum management; encouraging increased bandsharing as a beneficial activity for both incumbents and sharers; and recommendations specific to individual departments, focusing on their spectrum management processes. The Audit's recommendations are listed in full in the next section of this report.

The establishment of an effective spectrum management regime for the public sector is essential. Spectrum is a finite resource and one for which demand is projected to outstrip supply in the medium term – as shown by a demand study commissioned as part of our Audit. This will place increasing importance and pressure on spectrum managed by the public sector, and present both challenges and opportunities to public sector spectrum users. Analysis carried out by the Audit team estimates that the market value for current public sector spectrum holdings could be between £3bn and over £20bn depending on the methodology used. However calculating spectrum value is difficult, linked in part to the immaturity of the spectrum market, and the value of individual spectrum bands will differ significantly according to physical properties and past market and regulatory decisions.

In the past, the pressure on public sector users to make better use of their spectrum has been limited to their own expanding needs and the imposition of Administered Incentive Pricing. This report discusses the efficacy of AIP at its current levels and makes recommendations accordingly, but is of the view that these pressures have not led to spectrum usage being considered rigorously, or significant changes to spectrum management being introduced - both of which would be desirable. In most of the bands the Audit has examined, this has meant that equipment – with long procurement timescales before operation and then long lifecycles once in operation - has been designed to operate over whole bands, even if this might not be strictly necessary for technical reasons. There is therefore little scope for changes to many of these spectrum holdings to be made immediately. Instead, this Audit aims to put in place a spectrum management process which will ensure that spectrum needs are taken into account when equipment is designed and replaced, and that the economic and financial implications of using spectrum are introduced into the planning and budgeting processes of public bodies to improve efficiency of use into the future.

Market mechanisms

The Audit concludes that the application of market mechanisms to spectrum management in the commercial sector is likely to have a profound impact on the framework for managing spectrum in the public sector. New spectrum requirements will need to be met through the market in all but exceptional circumstances, as this is where the majority of spectrum available for use will lie in the future. Public bodies

will also be able to benefit from the gains of trading where they chose to engage with the market. Defining the spectrum 'rights' of Crown bodies will be key to enabling this, and the Audit recommends that Recognised Spectrum Access should be used for this purpose. Providing information about public sector spectrum use will also be key to facilitating a functioning market. The UK Spectrum Strategy Committee (UKSSC) should in future produce a Forward Look document every two years setting out a strategy for public sector spectrum management and future requirements.

Administered Incentive Pricing

The Audit recommends that the application of Administered Incentive Pricing (AIP) should be widened, to take account of areas which have previously not been subject to pricing. Pricing mechanisms are suggested for the valuable radar bands. It is also suggested that pricing should be applied to a previously unpriced NATO managed band used by the MoD. Changes to the overall AIP structure are also suggested. A review should be carried out of the pricing rates applied, with a view to addressing the current 'cliff edge' effect whereby those bands deemed 'fixed' and those classified as 'mobile' are charged vastly different rates which may be unrepresentative of potential alternative use. The Audit also suggests that Ofcom should ensure that the regular reviews of AIP rates are informed by both information about market values and by the effectiveness of AIP in practice.

Bandsharing

Geographic, temporal or technological reuse of bands is an attractive way to maximise use of the spectrum, particularly where the primary use is not continuous or nationwide. A significant amount of bandsharing already takes place in public sector spectrum, and the Audit is keen that this is enhanced and increased. This report examines two ways of doing this. Firstly, building on existing sharing techniques and arrangements by incentivising the bodies managing the bands to admit more sharers, for example by reducing their AIP charges commensurate with the value of sharing permitted, or allowing the bodies to keep the income generated from sharing arrangements agreed through the market. The second approach is to examine new technology-based opportunities for enabling sharing, perhaps in bands previously viewed as no-go areas for sharing. The Audit's aim in this case is to address potential barriers to such technology emerging, by, for example, the spectrum regulator facilitating a testing programme.

A possible barrier to the public sector engaging with the market, for example in negotiating access to bands on a shared basis, is the lack of commercial expertise and motivation in public sector bodies. The Audit is addressing this by suggesting that a third party be established, for a limited period, to act as an intermediary between public bodies and the commercial sector.

Band specific audit

The section of this report focused on auditing specific bands is a stocktake at one point in time of spectrum usage in major holdings. The recommendations in the rest of the Audit are aimed at putting in place a spectrum management structure that properly incentivises bodies to make the best use of their spectrum on an ongoing basis, so that auditing will be carried out by the bodies themselves and acted on.

The Audit has looked at just over twenty bands managed by the Civil Aviation Authority and the Ministry of Defence. Examining current and potential future use, the Audit has taken a view, based on the information made available, on the scope in

each of these bands for either releasing spectrum to alternative use or admitting additional services into the band on a shared basis, and given a traffic light marking accordingly. These are set out in detail in Annex B.

Where a red ‘traffic light’ verdict has been given (three occurrences), the Audit considers that there is currently little clear scope for making wider use of the band for the next five years. This does not preclude the possibilities changing in the longer term. Where an amber light is awarded (thirteen bands), the conclusion is that there is possibly some scope for enhanced use of the band but that either further work is needed before it is possible to make a final judgment, or that changes would not be possible immediately, for example due to the need for existing services to be reorganised or migrated out of a band. Where the Audit gives a green light to a band (eight bands) this signifies that in the Audit’s views there is scope in the short term for making alternative use of the band. The Audit also gives markings according to the potential for other action to be taken in the band, for example for pricing to be applied, or change to be pursued at an international level.

Selected fixed links bands have also been examined, and the Audit has concluded that there is no conclusive case for any immediate regulatory intervention, for example through clearance projects, to improve management in these bands. However, a number of bands examined pose significant spectrum management challenges. As the market develops it will become clearer whether the nature of licensing in Fixed Links bands is likely to inhibit trading and liberalisation in these areas and whether there is therefore a case for regulatory intervention to ensure efficient spectrum usage.

The Audit also recommends that Ofcom should run a one-off “Spend on Technology to Save on Spectrum” scheme. The Audit found that it is little known that Spectrum Efficiency Scheme funds, held by Ofcom, can be used to fund grants to promote efficient management and use of the spectrum, if the benefits outweigh the costs, so suggests actively seeking bids as a means of promoting this.

Spectrum Management Processes

The Ministry of Defence is already engaged in a process to improve its internal spectrum management, and the Audit comments on how this process can be used to improve coordination on spectrum issues within the department, and how spectrum requirements are taken account of in the procurement process. Reporting of progress against the MoD’s planned actions is suggested, as is the possibility of the application of targets at the next Spending Review to ensure that management of the MoD’s valuable spectrum resource is given appropriate priority if the incentives regime suggested in this report does not lead to a change in spectrum management behaviour.

The main area of focus for the Audit on the aeronautical side is the use of the radar, navigation aid and landing system bands. The application of pricing in this area is suggested, with proposed methodologies. Further work will be needed here to assess the value of the spectrum utilised by the aviation industry. Many of these bands are shared between civil and defence use. The creation of a new body is suggested to improve coordination and planning of these bands and to decide on the apportioning of charges in shared bands. The Audit also recommends that there should be a review of navigation aids and landing systems to determine whether there are too many levels of redundancy in these systems with a view to pressing for changes at a regional or global level.

The application of pricing to radar will also have an effect in the maritime sector, where the application of pricing is suggested for some licence classes. In the area of science services, the Audit is supportive of Ofcom's plans to introduce RSA for radioastronomy as a means of encouraging effective use of spectrum and the realisation of the value of spectrum use through pricing. The Audit has a preference for radioastronomy RSA to be made tradable as long as an appropriate incentive structure is in place, to allow those in a position to make more effective use of their spectrum to benefit financially from doing so.

The Audit is of the view that there needs to be both more of a focus on spectrum policy for the Emergency and Public Safety Services, and that there is a role for a band manager in managing the spectrum associated with these services. To achieve this, it is recommended that the role of the Public Safety Spectrum Policy Group should be recast to address these areas.

Review Point

The Audit has set out a process which aims to incentivise those who have most knowledge about their use of spectrum to improve the efficiency of this use. Given that the spectrum market is currently at an early stage of development, it seems sensible to review the effect of the spectrum management system recommended in this report, in five years.

Recommendations

Market Mechanisms

2.1 The Audit recommends that there should be a presumption that new public sector spectrum needs should be met through the market in all but exceptional cases.

2.2 The Audit recommends that, where there is an exceptional case where new spectrum needs cannot be met through the market, a process (set out in chapter 2) should be followed for assessing, through UKSSC, and against set criteria, the case for administrative assignment. Where this case is met Ofcom should be directed to make that spectrum available. Any costs involved should be met by the body or bodies responsible for generating the need.

2.3 Public sector spectrum should be considered for its trading potential and in principle be made tradable on a comparable basis to commercially held spectrum. Decisions will need to be made on a case-by-case basis depending on the suitability for trading of each RSA agreed.

2.4 Income generated from spectrum trading activities (including short term leasing and sharing arrangements) can be retained by departments, subject to capping arrangements. Departments should discuss this treatment with their Treasury spending team.

2.5 Ofcom should work with key public sector spectrum users to introduce RSA, beginning with priority bands where there is most necessity for usage to be recognised. Charges should be attached, based on AIP. The presumption should be that RSA should be tradable and convertible unless there is a good case otherwise.

2.6 UKSSC should produce a 'Forward Look' for public sector spectrum, every two years, including, for each of the public sector spectrum users who attend UKSSC: description of current spectrum use; changes to be made to allocations; changes to spectrum management; and quantitative predictions and justifications for future spectrum needs.

2.7 Ofcom should build on the analysis done in the demand study commissioned by the Audit team, and take forward future work as appropriate to gather background information on likely future spectrum demand and market developments.

2.8 Ofcom should seek to incorporate information about public sector spectrum usage and tradability in its public registers/databases.

2.9 There should be a review of the impact of the introduction of market mechanisms on public sector spectrum management in five years. Ideally, this should be independently led, but working with UKSSC. If the effect of the introduction of market mechanisms is not as envisaged by this Audit, the Government may wish to consider implementing a more interventionist approach, for example setting up an overarching spectrum management organisation for the public sector.

Pricing

3.1 AIP (Administered Incentive Pricing) is, and is likely to remain, a fundamental element in recognising the value of public sector spectrum use and encouraging improved spectrum efficiency. AIP should be extended to a wider range of public sector spectrum bands and uses.

3.2 When Ofcom next reviews the level of AIP the sharp distinction between the pricing of both public sector and commercial fixed and mobile services should be addressed. In the longer term Ofcom should move to a service-neutral per-MHz pricing system which reflects the spectrum value curve, subject to any relevant restrictions on use.

3.3 To formalise the application and enforcement of AIP fees for spectrum held by Crown bodies, pricing should be attached to public RSA on the same basis as AIP attaches to commercial WT licences. Until RSA are agreed, and in anticipation of the implementation of AIP changes recommended in this report, there should be a clear route for resolution of any disagreements over pricing levels (through the UKSSC structure). Government should also make a clear commitment to the principle of paying AIP charges on its spectrum holdings as requested by Ofcom, calculated on a comparable basis to commercial sector charges.

3.4 In future sharing or leasing arrangements should preferably be managed by the primary user (or a third party acting on its behalf), who would also receive payment direct from the secondary user. Where Ofcom manages the secondary use through granting licences or RSA, fees set in regulations should be linked directly to Ofcom receipts from the sharers, or to a sharing algorithm where that is not possible. The position on delegating charging functions should be clarified by Ofcom.

3.5 Where the MoD has partial use in a band used extensively for commercial services, the MoD should negotiate with and pay charges to the primary user directly where possible. If this is not legally or practically feasible the MoD should pay for its use to the extent that it restricts the scope and value of commercial activity. The RSA should be classified if necessary, for use by Ofcom and MoD only.

3.6

- (i) AIP should be extended to the 225-400 MHz band at the standard 'mobile' rate with appropriate discounts for sharing included. This should be done at the next appropriate point in the budgeting cycle, probably the 2007 Comprehensive Spending Review.
- (ii) AIP should be extended to the 3.1-3.4 GHz and 5.3-5.65 GHz military radar bands, charged on a national per-MHz basis. Pricing should be implemented on the same 2007-2009 timescale as for shared civil and military radar bands and on a comparable basis.
- (iii) The treatment of MoD bands below 3 GHz currently classed as 'fixed' should be reviewed to assess the case for pricing these at the 'mobile' rate instead.

3.7 We endorse the principle of AIP. To ensure the effectiveness of AIP as a tool, the periodic reviews of AIP rates should be informed by (i) market value of the spectrum being taken into account in AIP application and level; and (ii) reviewing the impact of AIP.

Bandsharing

4.1 In parallel to the work to establish RSA for Crown bodies, the NFPG should agree and codify existing sharing arrangements, beginning with the priority bands for RSA. These agreements could then be annexed to the relevant RSA.

4.2 A third party body should be set up to act as an intermediary between public bodies and commercial interests. This should be funded from the Spectrum Efficiency Scheme for a pilot period of 18 months to provide free facilitation of trading and sharing arrangements for public bodies (with an element of profit-sharing built in).

4.3 MoD, CAA, MCA and Ofcom should agree a specification for a test programme to be carried out on the use of bandsharing technologies to allow sharing between radars and communications systems. Once PSSTG requirements have been agreed, and the testing programme is underway, there should be a presumption in favour of sharing being admitted with any technology meeting these criteria. Ofcom should facilitate the test programme, providing testing capabilities; the incumbents should provide reasonable help as necessary. If the testing programme reveals specific technology barriers to a promising technique being introduced, Ofcom should consider whether this merits further research funding from the Spectrum Efficiency Scheme to address these problems.

4.4 CAA and MoD should make spectrum available for sharing trials in the 2.7-3.4GHz band on a spatial or time basis.

4.5 A bandsharing group consisting of Ofcom, MoD, CAA and MCA should be established. Issues are suggested for early consideration by the group. The group should form a sub-group of the formal UKSSC structure.

Ministry of Defence

5.1 MoD should report, in the UKSSC Forward Look document, on its future plans for management of its spectrum holdings in the light of the Audit's band specific analysis and its own current benchmarking and future scenario planning work.

5.2 MoD should report to UKSSC on progress in implementing its spectrum policy in the first Public Spectrum Forward Look document. In particular, attention should be paid to the areas highlighted in this report.

5.3 Setting spectrum targets should be considered further in discussions between MoD and HM Treasury in the context of the 2007 Comprehensive Spending Review, when overall targets will be revised.

5.4 The MoD should produce an implementation plan for delivery of its spectrum policy with respect to spectrum in the UK, including timescales and responsibilities clearly identified and allocated.

5.5 The Audit recommends, with regards to the SAA: (i) that its Terms of Reference encompass the roles envisaged in Chapter 5; (ii) that the SAA consider amending acquisition requirements to include spectrum as an input for consideration; (iii) that the operation of the SAA is reviewed after one year and reported on in the Public Spectrum Forward Look document; and (iv) at this stage a decision should be

made whether spectrum fees should be transferred to the SAA for management or disaggregated within the Department.

5.6 Spectrum Efficiency Scheme funds should be made available to part fund, with the MoD, research into systems to enable MoD bands to be more dynamically managed and to increase sharing possibilities. Ofcom and the MoD should agree on a joint budget and specification for this work and manage the project together.

5.7 The Audit recommends that MoD should review its resource allocation to spectrum management in the light of the more active spectrum management role recommended by this Audit and envisaged in the MoD's spectrum policy document.

Aeronautical

6.1 AIP should be extended to military and civil aeronautical uses of the spectrum where it has the potential to help increase efficiency of spectrum use now or in the medium to long term. Beneficial effects of pricing could include:

- Maximising the benefits to aviation of its existing spectrum holdings
- Recognising and enabling other potential uses of the spectrum (where alternative use would be possible)

6.2 CAA and MoD should report their future plans for management of aeronautical spectrum holdings in the UKSSC Forward Look document, including progress on the opportunities for spectrum release or additional sharing identified in the Audit's band specific analysis (see Annex B). Plans for shared civil/military bands should be coordinated through the new radar and aeronautical subgroup of UKSSC.

6.3 Initial AIP charges should be set conservatively, in line with Ofcom policy for other AIP classes. As part of this process Ofcom will need to evaluate the opportunity cost of existing aeronautical spectrum use to an aviation user denied or granted spectrum use at the margins.

6.4 As co-ordination between the regulator and individual users will generally be needed to enable redeployment of aeronautical spectrum, where possible pricing should be imposed as an overall per-MHz band price. It would then be the responsibility of a co-ordinating body to apportion the band price and work with users to enhance intensity of use or release spectrum. Algorithms which reflect impact on other spectrum users should be employed where this is not feasible (or desirable if it could create perverse incentives).

6.5 For other airborne uses where the opportunity cost is effectively zero and there is no direct spectrum management pricing should remain at cost-recovery levels for the moment (Ofcom are considering options including a fee-free system for aircraft licensing). Currently cost-recovery licences do not always very accurately cover the true licensing costs, and where this is the case the pricing structure should be reviewed.

6.6 AIP should be introduced on the basis of both the value to aeronautical users and potential alternative users in all ground-based radar systems:

- UHF Radar (subject to decisions on clearance)
- L-Band
- S-Band
- X-Band
- Ku-Band

6.7 There may be a case for pricing DME ground stations, since they are licensed with discrete and potentially scarce assignments. The case is not clear-cut but Ofcom should assess the case for pricing DME further as part of the exercise in determining the scope and level of aeronautical AIP to be implemented.

6.8 The MLS allocation is currently underused and there may be a case for applying pricing to this spectrum on the same basis as ground-based radar sites. This is subject to a concern that disproportionate pricing on initial users should not discourage the adoption of an effective technology, and potential pricing of MLS should be linked to a review of navigation aids and landing systems as below.

6.9 There may be an economic case for differential pricing of ground-based and/or airborne VHF communications licences to accelerate adoption of more spectrally efficient equipment in congested spectrum. Ofcom should investigate the opportunities further, in conjunction with CAA.

6.10 Ofcom, CAA and MoD should undertake a joint review of navigation aids and landing systems to consider whether any rationalisation of multiple allocations is feasible. The opportunities identified should be pursued through pressing for changes at a regional or global level, and through the use of market mechanisms where possible.

6.11 Ofcom, with assistance from the CAA, should take forward discussions with the incumbents of the 590-598MHz band with a view to vacating the band (including the option of a funded clearance project). These discussions should take place in the context of the wider debate on broadcasting spectrum in RRC06 in order to properly assess the costs and benefits of such action.

6.12 Radar tends to produce significant levels of unwanted emissions which can adversely affect the intensity of use and hence value of other spectrum bands. The Audit considers that there is an economic case for taking account of these negative externalities through a system of penalties on radar users for the degradation they cause to spectrum use in other bands. Further research and proposals on this issue should be taken forward by Ofcom in parallel with the extension of AIP to radar.

6.13 As part of their response to this Audit, Government, Ofcom and the CAA should jointly adopt and publish a timetable for consulting on and implementing AIP for appropriate aeronautical spectrum classes. In the Audit's view implementation of AIP could realistically take place in line with Ofcom's plan to introduce trading in appropriate aeronautical licence classes between 2007 and 2009.

6.14 The arrangements for joint CAA and MoD coordination of aeronautical bands should be formalised, perhaps including the use of a joint planning tool. A new radar and aeronautical subgroup of UKSSC should be constituted with a membership of Ofcom, CAA, DfT and MCA. This group could be established in 2006, in advance of the introduction of AIP. Its eventual remit would be to:

- Apportion fees between individual users and collect them
- Take decisions on competing demands for spectrum
- Manage detailed compatibility and planning
- Use a joint planning tool to enable more efficient and dynamic assignment

Maritime

7.1 Ofcom, in conjunction with the MCA, should begin work to introduce Administered Incentive Pricing in the following licences classes: Navigational Aid (radar); Coastal Station (UK) radio; and Differential Global Positioning System (DGPS); including carrying out further work on future demand as indicated in this chapter. This should be carried out to the same timing as the development of aeronautical pricing where there are linkages.

7.2 The MCA should examine in detail the possibility of increasing sharing in the 3 GHz and 9 GHz maritime radar bands, and should report on this issue to the Sharing Group for discussion with other users of these bands.

7.3 Ofcom and the MCA should carry out a review of international applications in the bands 156.0 MHz to 158.5 MHz and 160.6 MHz to 163.1 MHz to ascertain the feasibility of promoting simplex use of the duplex channels and/or the conversion to 12.5 kHz bandwidths.

Emergency and Public Safety Services

8.1 The role and composition of PSSPG should be reviewed:

- The Audit recommends that PSSPG focus on policy rather than technical issues, and attendance at the group amended accordingly;
- PSSPG should consider whether it, or a contracted party, should act as a band manager for public sector spectrum. If the former, PSSPG will need more staff resource.
- Section 8.2 sets out some roles that PSSPG should fill
- PSSPG reporting lines should be changed so that PSSPG reports directly into UKSSC. Ministerial reporting should be examined.
- In addition, future needs of all the services need to be properly assessed, and coordinated through PSSPG. If PSSPG sponsor departments cannot do this they should fund contracted work.

Science Services

9.1 Subject to resolution of incentives issues as set out in Chapter 9, radioastronomy RSA should be made tradable.

9.2 PPARC should review the structure for devolving spectrum charges, and consider (in the light of discussions on income retention) either cascading charges to users or taking a more active role in spectrum management, to enable pricing to be applied at the level of those able to make decisions about the use of spectrum by these services.

9.3 The budget for spectrum charges for the bands used by the Met Office should be transferred from the MoD to the Met Office to be managed there. MoD and the Met Office may wish to review the use of these bands before this transfer takes place.

Fixed Links

10.1 Ofcom should review the 1.4 GHz and 1.5 GHz bands in the light of the market value and environment revealed by the upcoming auction of adjacent L-Band spectrum. Ofcom should then give further consideration to the merits of a clearance project or overlay auction as appropriate.

10.2 With regard to 1790-1798 MHz:

- (i) Ofcom should pursue the resolution of the issues currently affecting the possibility of a successful auction, aiming for an award as they currently plan, in 2007/8;
- (ii) The MoD should pay Administered Incentive Pricing for this band;
- (iii) The option of migrating the MoD use out of this band into an internationally harmonised space operations band, probably over a longer timescale of 10-15 years, should be considered as an option for this band

10.3 Ofcom should consider the use of RSA for receive-only satellite earth stations in the 3.6-4.2 GHz band, along other options for improving the management of this band.

10.4 The Audit recommends that Ofcom gives priority to gathering information to enable it to decide whether, when and on what terms the introduction of RSA in the 11 GHz band would be beneficial.

10.5 If the market study being carried out reveals significant demand, Ofcom should give the 32GHz award a high priority in the interests of encouraging efficient spectrum management and obtaining information about the likely effect of the market in Fixed Links.

10.6 Ofcom should run a one-off 'Spend on Technology to Save on Spectrum scheme' of around £500k. Criteria are suggested in Chapter 10.

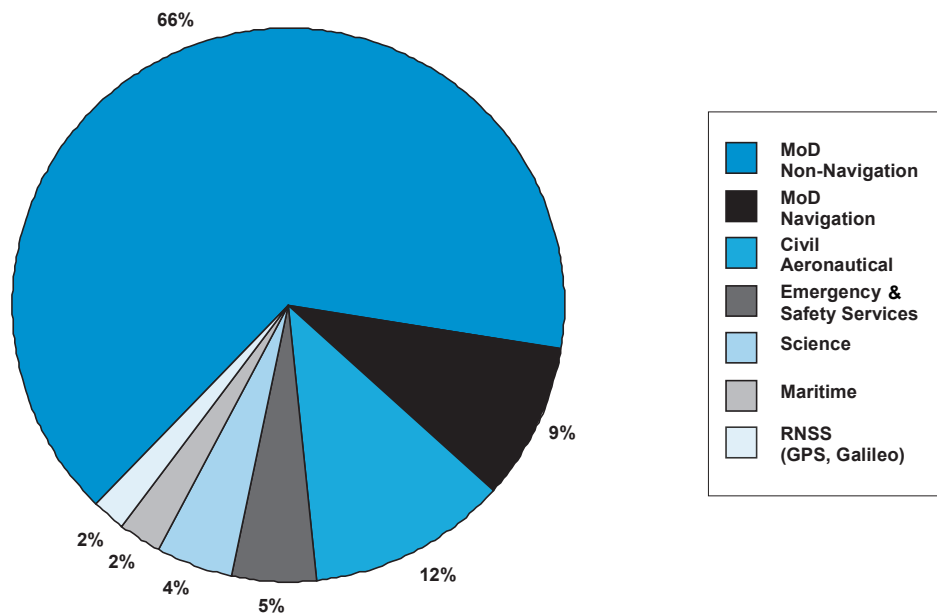
Introduction

The Review of Radio Spectrum Management, carried out in 2002¹, set an agenda for the widespread application of market mechanisms in commercial spectrum management. Ofcom are in the process of rolling out trading and liberalisation and this year confirmed their plans to move progressively from a ‘command and control’ system run by the regulator, to over 70 per cent of the spectrum being managed through market mechanisms by 2010.² This is to be accompanied by a programme of awards of available spectrum.

Spectrum management by market forces is already in place in New Zealand and Australia, and there is increasing interest in the role of the market in managing spectrum elsewhere. The European Commission recently published a Communication³ which proposed the coordinated introduction of spectrum markets across the EU, estimating that approximately one-third of the spectrum below 3 GHz could be made subject to trading and liberalisation by 2010 and setting out its view that significant benefits could flow to the EU from such a move.

With these changes to the commercial spectrum management environment underway, it is timely to consider the spectrum management regime for the public sector. The public sector⁴ accounts for just under half of all spectrum use below 15 GHz – the frequency range being covered by this Audit. This use is broken down as shown below:

Figure 1: Composition of public sector spectrum holdings below 15 GHz



¹ Review of Radio Spectrum Management, <http://www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review>

² <http://www.ofcom.org.uk/consult/condocs/sfr/sfr/>

³ A market-based approach to spectrum management in the European Union, COM (2005) 400.

<http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:52005DC0400:EN:NOT>

⁴ For the purposes of this Audit, the term ‘Public Sector’ is used to cover the following uses of spectrum: defence; aeronautical (civil and military); maritime; science services; emergency and public safety services.

The majority of spectrum allocations to public sector bodies were made some years ago by administrative assignment ('command and control'), when there was little spectrum scarcity and therefore no pressure for public sector users to consider the efficiency of use of their spectrum resources. A summary of public sector spectrum use and the main spectrum management policy issues it raises was given in the Audit's consultation document issued in July.⁵

This is no longer the case. As supporting evidence for this Audit, a study was commissioned into potential future demand for spectrum from the commercial sector (again, below 15 GHz)⁶. The study concluded that on a base case macro scenario covering all services examined, demand would exceed supply by 2.5 GHz by 2025. Demand varies by band – in summary, there is likely to be high demand between 0-1 GHz and 6-15 GHz and moderate demand for spectrum between 1-3 GHz and 3-6 GHz.

The demand study adopted a scenario-based approach to projecting forward demand. The number of variables affecting any possible demand outcome was clearly illustrated through this approach, demonstrating the difficulty in predicting one specific outcome with any certainty. This suggests that any approach involving second-guessing where future demand is likely to fall - and taking steps to mandate the clearance of such spectrum - is likely to lead to an ineffective allocation of resources. Instead, a more flexible and responsive approach to spectrum management is likely to be more appropriate, enabling needs to be met through allowing market forces to signal the demand for public sector spectrum, addressing needs as they arise in the medium to long term.

Currently the main tool for encouraging the effective use of public sector spectrum is Administered Incentive Pricing (AIP), which is applied to the public sector on a comparable basis to the commercial sector and is intended to reflect the opportunity cost of the current use of that spectrum. The Ministry of Defence (MoD), for example, whose spectrum use this Audit examines, currently pays £55 million a year in AIP fees. This is the largest sum paid by any individual spectrum user, reflecting the fact that the MoD accounts for around three-quarters of public sector spectrum use. However, AIP is not currently applied to all MoD bands.

The international spectrum management framework is important in the consideration of public sector spectrum usage. For some services of an international nature, such as those in the aeronautical and maritime sectors, it may be that spectrum is internationally harmonised for a particular purpose to enable international interoperability. This may constrain the scope that the UK has to make changes to spectrum usage unilaterally. In such areas, where there is a case for changes in spectrum usage these may need to be pursued in European or International fora.

Some recommendations in this report have financial implications. In many cases it is suggested that these should be addressed as part of the Comprehensive Spending Review (CSR). The CSR will conclude in 2007 and will set budgets for the three years from 2008-09 to 2010-2011.

⁵ Emerging Issues: A Consultation Document, July 2005, http://www.spectrumbaudit.org.uk/pdf/Emerging_Issues.pdf

⁶ Spectrum Demand for non-Government Services, September 2005, http://www.spectrumbaudit.org.uk/pdf/spectrum_demand.pdf

Market mechanisms

2.1 Introduction

The Audit considers that there are significant implications for public sector use of spectrum from the introduction of market mechanisms on the commercial side. It supports action to introduce market mechanisms into spectrum management as an effective way of allowing the optimal use of spectrum to be realised. This chapter sets out the Audit's view on the opportunities and challenges presented to the public sector from the introduction of market mechanisms into spectrum management.

The study carried out for the Audit on commercial demand for spectrum is summarised, conclusions drawn from this, and recommendations made about making information about public sector spectrum usage available as a necessary part of developing the spectrum market. This report confirms the view outlined in the Audit's consultation document that Recognised Spectrum Access should be used to define the spectrum usage of Crown bodies, and to enable trading, and that the UK Spectrum Strategy Committee should produce a regular Public Sector Spectrum Forward Look document, covering strategies for spectrum management and future needs.

2.2 Meeting new spectrum requirements

The Audit's view is that there should be a presumption that public sector requirements for new spectrum should be met through the market. Some respondents to the consultation questioned why the current 'command and control' approach could not be maintained. The Audit does not see that the status quo is an option. It is not feasible to keep public sector spectrum, managed in a command and control way, completely distinct from the commercial side, where market mechanisms are being introduced. In meeting new needs, for example, market engagement will be a necessity, as that is where the majority of candidate spectrum will lie in the future and Ofcom may not hold empty 'spare' spectrum to assign administratively. In addition, the process of administrative assignment is unlikely to be economically optimal or the best means of exposing public sector users to the full cost of their spectrum use.

Respondents to the consultation expressed concern that requiring new demands to be met through the market might affect the operational capability of safety or security-critical services. The Audit recognises that there may be some exceptional cases where needs cannot reasonably be met through the market. These incidents are more likely to arise in the short term, before the spectrum market is fully developed. In these cases, if certain criteria are met, the Audit proposes a process, set out below, for the regulator to intervene to make an administrative assignment. The Audit considers that this process provides a safeguard for meeting critical needs if the market cannot meet them.

It is worth noting that many bodies regarded as 'public sector' (e.g. local authorities) already secure their spectrum in a similar way to the commercial sector.

Recommendation 2.1: The Audit recommends that there should be a presumption that new public sector spectrum needs should be met through the market in all but exceptional cases.

The Audit's consultation document set out and asked for views on a suggested fallback process and criteria to ensure that administrative assignment should be used only in exceptional circumstances and only where there is an essential requirement, no workable alternative and with a full consideration of the wider economic implications. A number of respondents agreed that there should be a fallback process for administrative assignment where there is an important public policy dimension, but we did not receive any specific comments on the proposed criteria. The Audit therefore suggests that the process and criteria below are adopted. Where the criteria are not met there would be no administrative assignment and needs would have to be met another way, e.g. through the market. The process contains two changes from the version set out in our consultation document:

1. That if an administrative assignment is deemed necessary and there are costs involved in that (e.g. through revoking a licence/ paying compensation) then these costs should be met by the body/bodies generating the need, in addition to AIP being applied subsequent to any assignment. The Audit concludes that this is the fairest outcome (rather than for example a single department such as DTI – which may not have generated the need - being responsible for meeting costs) and also the most effective means to ensure that needs have been fully thought through and that alternative acquisition routes (e.g. through commercial contract or direct market acquisition) have been equally considered.
2. That there should be a specific requirement for UKSSC on behalf of the government to consider whether there are any legal barriers – e.g. state aids – to making such an assignment. We understand for example that there are more difficulties making a spectrum award if the recipient is not covered by Crown immunity and therefore needs to be licensed.

It is suggested that this process should be applied to large or contentious requirements. Where minor assignments are being made on a first-come-first-served basis and there is no significant potential for distortion (e.g. no excess demand for the spectrum under consideration) a decision could be reached through the relevant UKSSC sub-group.

Box 1: Criteria and process for administrative assignment

1. The department concerned would need to make an initial request to UKSSC or the relevant subgroup for a non-market assignment. For further consideration this would have to meet the following criteria:
 - Demonstration of safety or security critical requirement, or mandatory international obligation
 - Demonstration that needs cannot reasonably be met through existing allotments or allocations, including through more intensive use of existing bands
 - Demonstration that needs cannot reasonably be met through the market
 - No alternative means of providing service
2. Escalate from subgroup to UKSSC if the subgroup considers these criteria are satisfied. Government should then liaise with Ofcom through UKSSC to obtain Ofcom's view, including an assessment of the value of the spectrum, the market impact of an administrative allocation, legal questions, and whether Ofcom have appropriate spectrum available.
3. If the UKSSC concluded after advice from Ofcom that an administrative assignment could be made, and is satisfied that there are no legal barriers for doing so (e.g. state aids) the DTI Secretary of State should issue a ministerial direction under the 2003 Communications Act instructing Ofcom to make the spectrum available:
 - If spectrum was available Ofcom could then assign this
 - If there was no spectrum available, the body/bodies generating the need would have to guarantee to provide any funds needed to make spectrum available, through a standard trade or licence revocation, with compensation where it can be justified and is necessary.

Recommendation 2.2: The Audit recommends that, where there is an exceptional case where new spectrum needs cannot be met through the market, a process (set out in Box 1) should be followed for assessing, through UKSSC, and against set criteria, the case for administrative assignment. Where this case is met Ofcom should be directed to make that spectrum available. Any costs involved should be met by the body or bodies responsible for generating the need.

2.3 Budgeting for spectrum acquisition

The Audit team recognise that there will be costs involved in meeting new spectrum needs. This will apply whether a market route is taken or an exceptional case proven and administrative assignment made involving Ofcom revoking a licence and incurring a cost for doing this. It is therefore important that public sector bodies have good forward planning processes in place to identify their spectrum needs at a sufficiently early stage to budget for this. Once these needs have been identified and the likely costs examined, the Audit can confirm that a body within the standard public expenditure framework has a number of options for satisfying needs and budgeting for costs:

- (i) Include spectrum as an input in a procurement contract, so that the costs are met by a contractor as part of the contract.
- (ii) Purchase spectrum on a time limited basis. Annual 'rental' payments for spectrum which was not purchased as an asset would score to the resource budget.
- (iii) Buy the spectrum outright. Where spectrum is purchased as an asset, the cost would score to the Department's capital budget.
- (iv) Have spectrum managed by a band manager. Somewhat like option (i) but with a band manager acquiring spectrum as necessary rather than providing the whole service.
- (v) Where Ofcom continues to licence geographically shared bands, for example fixed links, public bodies could be granted rights alongside and on the same basis as commercial users (where the required levels of protection and future certainty can be provided).

As with other input costs, this places high importance on the public body being able to plan for and therefore factor future spectrum costs into budgeting and spending review processes, which are designed to judge the priorities of government and allocate resources accordingly.

As set out in the consultation document, if steps such as these are taken within the context of a liberalised spectrum management framework, we do not regard the possibility of high prices as an obstacle to acquisition of spectrum by the public sector, because in a properly functioning market the level of prices will reflect the value of alternative uses. The public sector would acquire spectrum, as it does other inputs, at commercial rates. Key to this is identifying and planning for spectrum needs and their likely cost sufficiently far in advance. Our suggestion in Section 2.8 of the production of a forward-looking public sector spectrum strategy is designed to kick start this process in public bodies.

2.4 Trading

Placing the responsibility on the public bodies themselves for meeting new spectrum requirements through the market means that they should also be able to benefit from the gains of engaging with the market, if they wish to undertake such activity. Bodies will of course gain if they are able to use spectrum more efficiently, reduce their needs and therefore pay less AIP. However, we are also keen that bodies should be more actively encouraged to make better use of their existing spectrum holdings, by being able to retain income from trading activities (see 'Incentives' section below). This may in fact be higher than the value reflected by AIP (if AIP is set conservatively – see chapter 3 for a discussion of this). The Audit believes that the integration of public sector spectrum holdings into the market will have a positive effect on the spectrum market overall.

A question raised in response to our consultation was whether it was *appropriate* to trade public sector spectrum. A key point here is that where trading is introduced, it will be for the public body to decide whether or not to engage in trading. There is no element of compulsion and the bodies themselves will therefore decide on the scale of their trading activities, carrying out risk assessments as necessary. The Audit is not mandating a trading approach, but instead enabling it for those bodies who consider it appropriate for them given their operational requirements and needs. Ofcom's plans for introducing trading already set out a timescale for the introduction of trading into some spectrum used by the public sector (for example, introduction into emergency services spectrum with a timetable of 2006 at the earliest - and decisions on aeronautical and maritime use to be made between 2007 and 2009).

The CAA have expressed their view that aeronautical spectrum is not in general suitable for trading. As set out in Section 6.10 the Audit considers that aeronautical pricing and trading decisions should be taken forward in parallel, and there will be an important role for the new radar and aeronautical subgroup of UKSSC in working through the applicability of trading to aeronautical spectrum.

The Audit appreciates that there may be some licence classes where trading is not feasible – for example where there are international provisions which preclude change of use and there are no other same-services users. The Audit's view is however that, in principle, public sector spectrum should be made tradable on a comparable basis to the commercial sector. In practice, decisions will need to be made on a case-by-case basis. The introduction of Recognised Spectrum access (RSA) for the public sector, suggested below, would facilitate this process as for each RSA it will need to be decided whether the RSA is (i) convertible to other use and (ii) tradable.

Recommendation 2.3: Public sector spectrum should be considered for its trading potential and in principle be made tradable on a comparable basis to commercially held spectrum. Decisions will need to be made on a case-by-case basis depending on the suitability for trading of each RSA agreed.

Responses to the consultation document commented that the public sector would not be properly equipped to deal with commercial spectrum transactions. The Audit recognises that this is a potential barrier to the public sector engaging with the market, and has therefore suggested that there may be a role for a third party intermediary to carry out this function for a limited period of time whilst expertise is built up and experience of the market gained (as suggested in the consultation document and explored in more detail in Chapter 4 on bandsharing). It should also be noted that many public sector bodies are already adept at engaging in commercial transactions and that this is complementary to Government-wide moves to encourage departments to make better use of their assets in general.

2.5 Incentives

AIP is currently the main market mechanism used to incentivise efficient use of public sector spectrum. As the market develops it is hoped that information about market values will contribute to AIP values being more closely aligned to the opportunity cost to other potential users. If bodies are able to make more efficient use of their spectrum and release bands to the regulator, they benefit from not paying the AIP charge. However AIP is a relatively conservative and lagging indicator of value. The Audit is keen that an incentive structure is put in place which encourages bodies to also be more active in their management of spectrum, to react in a timely manner to changes in the value of their spectrum holdings, and to gain financially from doing so.

The Audit team has discussed with HM Treasury the treatment of proceeds generated by public bodies making more efficient use of their spectrum by leasing or selling it in the market, and can clarify that public bodies generating income from the sale or lease of their spectrum will gain financial benefit through retention of the income generated, subject to capping arrangements to prevent windfall gains. The Audit recommends that this is pursued by departments in conjunction with their spending teams.⁷

⁷ It is noted that the CAA receives no public funding but is regulated in terms of charges and cost recovery by Treasury, including the requirement to make a 6% return.

Recommendation 2.4: Income generated from spectrum trading activities (including short term leasing and sharing arrangements) can be retained by departments, subject to capping arrangements. Departments should discuss this treatment with their Treasury spending team.

The Audit's consultation noted the possibility of creating spectrum as an asset on department's balance sheets. Although in theory it could be possible to effect this change, the Audit considers that there is little additional benefit to doing so at this stage, given that the asset treatment of acquisitions and income treatment has been clarified.

2.6 Defining rights

As set out in the Audit's consultation document, many public sector bodies are not able to hold WT Act licences for spectrum due to 'Crown immunity'⁸. This raises two main issues in relation to public sector spectrum management:

1. Interference management:
 - Public sector bodies are concerned that their existing allocations may not be sufficiently recognised as trading and liberalisation are introduced. Without formal recognition, such as that provided by RSA with the concomitant duty on Ofcom to take account of the usage in question, the Audit considers that this is a valid concern. This applies particularly to existing shared bands, and also change of use in adjacent bands where this was originally agreed based on compatibility studies with public-sector use.
 - Many of the planned spectrum awards rely on management and coordination with public sector bodies to define usage and parameters. This can be a resource intensive and time consuming process which could potentially delay awards – if rights were better defined it would ease this process.
2. Trading. It is necessary to define what 'rights' are being traded to negotiate a transaction and effect a trade.

In the course of the Audit's discussions it has become apparent that there are some uncertainties about the licensing situation in bands regarded as public sector. For example we have been told that there are some Crown bodies which currently do hold WT Act licences (perhaps granted due to a lack of understanding of their status as covered by Crown immunity). In other cases there appears to be a lack of clarity about the licensing status of commercial operations carried out in bands managed by the public sector. The Audit hopes that through the process of defining public sector spectrum rights, as suggested here, these issues will emerge and be resolved. The use of RSA as a tool - as discussed below – may help in some instances.

2.7 Recognised Spectrum Access

The Audit's consultation document set out some options for defining the rights of public sector spectrum holders and stated the Audit's preferred solution of applying Recognised Spectrum Access (RSA) to the public sector.

Sections 159 and 163 of the Communications Act allow Ofcom to make grants of RSA to bodies covered by Crown immunity. The applications considered to date by

⁸ For more information on the treatment of the Crown see http://www.ofcom.org.uk/radiocomms/ifi/licensing/licensing_policy_manual/what_is_Crown_body?a=87101

Ofcom for RSA applicability have been for receive-only services. However, there is nothing in the legislation that prevents RSA being issued in respect of transmission by Crown bodies as transmission by such bodies does not require a WT Act licence.

Some responses to the consultation document expressed doubt about how RSA would work, as it has yet to be tried in practice. Others queried whether this tool was needed. As it is not possible for Crown bodies to be granted a WT Act licence without changing the law, RSA is a 'quasi-licence' tool for recognising the spectrum usage of these bodies, which the Audit considers is necessary for effective spectrum management. RSA as opposed to amending the WT Act to make licences applicable also to public bodies is the Audit's preferred action given (i) the difficulty and likely timescale involved in amending legislation and (ii) the wider potential offered by RSA e.g. to define receive-only services.

In terms of experience of implementing RSA, the first application (for radio astronomy) is due to be introduced in 2006. A consultation document was published in 2005 followed by a statement on 17th October⁹ which set out how RSA would be applied. This will provide some useful experience of RSA working in practice, although the circumstances of Crown RSA would be somewhat different. As explored below, it is likely that RSA for Crown bodies would have some similarities to WT Act Licences.

The Audit team have discussed the potential application of RSA to Crown bodies with Ofcom. The nature and technical characteristics of any particular RSA will depend on the service and band being considered and whether it is designed to cover transmission and reception or just reception. For illustration, an RSA could cover:

1. The operational characteristics of individual services to be defined – e.g. with a radar band like 2.7-2.9 GHz the characteristics of each military ground station would be covered. The technical parameters would be similar to those in a WT Act licence (possibly already used for parallel civil use in the same band), e.g. specifying frequency, bandwidth, power, purpose and location of transmitter. Both transmitters and receivers could be included.
2. Conditions to be applied based on a spectrum mask, generalising the transmission parameters and defining the level of acceptable interference from others in a defined geographical area. In this way RSA could be drawn up for the whole band, with a spectrum mask for transmit and receive.

It would be up to the body concerned to decide which option to pursue. Ofcom is permitted to charge fees for RSA reflecting the economic value of the spectrum in question. In the case of Crown bodies AIP would provide a suitable basis for pricing. The pricing for the RSA would reflect how much spectrum was being recognised and therefore the restrictions placed on alternative use. An exclusive RSA covering a whole band would be more costly (for example equating to the full AIP for that band) than one defining individual ground stations (which would leave other parts of the band open to potential other use, reducing flexibility for the RSA holder but incurring lower charges). The greater the bandwidth and area covered the higher the fee would be. The design of the RSA would also affect what was possible through trading and change of use:

⁹ A statement on applying RSA to Radio Astronomy, October 2005, <http://www.ofcom.org.uk/consult/condocs/astronomy/statement/statement.pdf>

- Partial trades are possible - by time, location, frequency – as are concurrent trades where the obligations and rights are shared by the transferor and transferee;
- Transfers may also be in perpetuity or time limited;
- As set out in recommendation 2.5, the Audit is in favour of RSA being made tradable wherever possible;
- Holders of an RSA may seek its conversion to a licence in accordance with Ofcom regulations e.g. at the point of sale to a commercial user;
- The take-up of RSA would be on a voluntary basis.

The Audit is of the view that RSA will offer benefits for all parties: the regulator – in managing the market in adjacent bands and with shared users; the bodies themselves – in having some guarantee of their recognised rights; and for commercial spectrum users. **The Audit therefore considers that the introduction of RSA for Crown bodies should be a priority for both Ofcom and the bodies themselves.** Given the complexity of use in some of the bands which may be suitable for RSA, this is likely to be a resource-intensive activity. In the Audit's view this should be allocated sufficient resources accordingly.

There is a wide range of bands used by Crown bodies which could potentially be covered by RSA. It therefore makes sense to identify priority bands for addressing first. The Audit's view is that these priority areas should be: (i) the bands with existing sharing arrangements, where most benefit could be gained from more clarity over usage parameters and which might be the bands most suitable for trading activity; (ii) bands identified in Ofcom's SFR:IP in which there is related public sector use (iii) those given a green or amber marking in Annex B and which may therefore have scope for release or increased sharing.

The Audit recognises that there are circumstances where it would be problematic for details of some public sector RSA to be published. In these cases it would seem appropriate for a 'classified' RSA to be drawn up and used for planning purposes by those with appropriate security clearance at Ofcom but not published, as long as the reasons for non-disclosure are made clear.

Recommendation 2.5: Ofcom should work with key public sector spectrum users to introduce RSA, beginning with priority bands where there is most necessity for usage to be recognised. Charges should be attached, based on AIP. The presumption should be that RSA should be tradable and convertible unless there is a good case otherwise.

The Audit considers that the agreement of RSA for Crown bodies is complementary to Ofcom's move to develop spectrum usage rights, as the parameters agreed as part of an RSA are likely to be similar to usage rights.

2.8 UK Spectrum Strategy Committee

The Audit has considered the role that UKSSC plays in coordinating public sector spectrum strategy and management. It is of the view that UKSSC is an effective forum, convened at the right level and status (as a Cabinet Committee) with the correct attendees. Elsewhere in this document we suggest enhanced roles for UKSSC through the creation of two new sub-groups (on radar/aeronautical issues and bandsharing) and through strengthening the role of PSSPG as a policy forum. See Annex G for a flowchart of the Audit's proposed structure

2.9 Future public sector needs

The Audit's consultation document also suggested an expanded role for UKSSC in coordinating future strategy and spectrum requirements for the public sector as a whole. There were no dissenting replies, and the Audit therefore recommends that this should go ahead as set out in the Emerging Issues document. UKSSC should produce a 'Forward Look' for public sector spectrum, every two years. Support from Ofcom in an advisory role is likely to be needed but it should be for departments themselves to coordinate and produce the strategy for their service/organisation. It would be for UKSSC to decide whether parts of the strategy should not be published – for example due to commercial or security sensitivities.

The strategy should include, for each of the public sector spectrum users who are members of UKSSC:

1. Description of current use of spectrum
2. Changes to be made to allocations e.g. handing over management of bands
3. Changes to spectrum management e.g. introduction of trading or leasing
4. Quantitative predictions and justifications for future spectrum needs (the identification of which could lead to consideration of how to address them and the start of the process identified above for seeking new spectrum if necessary). These should present a detailed ten year view with projections extending to twenty years

The Audit has been discussing future public sector needs on a bilateral basis with the relevant departments. Some organisations do envisage future requirements outside their existing allocations, but none have yet reached the stage of fully articulating their requirements in terms of bandwidth and frequency needed. In the Audit's view this supports the case for an overarching strategy to be produced to crystallise and articulate these needs, as discussed above. The information provided by bodies has been factored into the specific band analysis where appropriate. It is appreciated that the first version of this Forward Look document may not contain a comprehensive assessment of future needs for all bodies, given the nature of work which will have to be undertaken to produce a useful and accurate assessment, but this can be built on in future iterations.

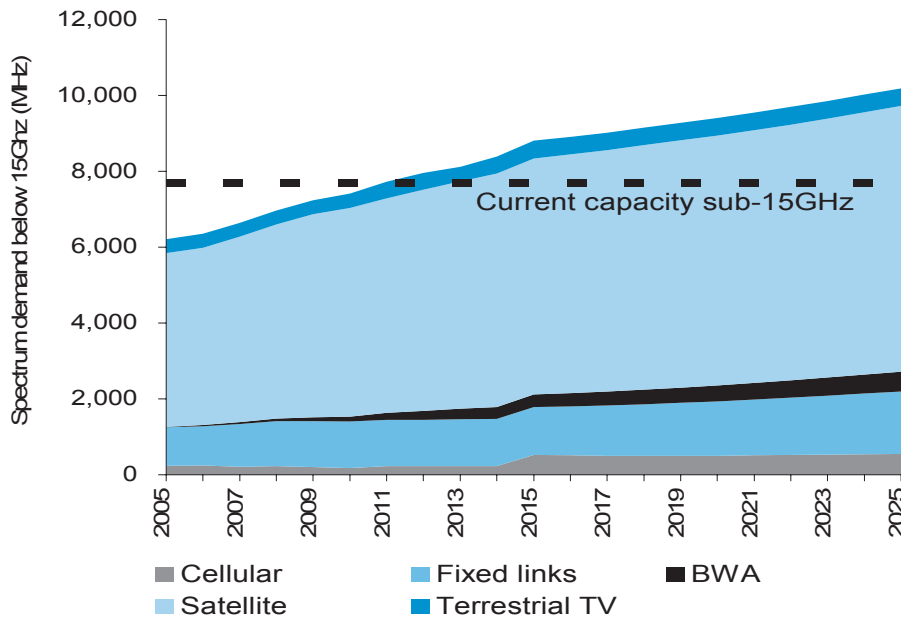
Recommendation 2.6: UKSSC should produce a 'Forward Look' for public sector spectrum, every two years, including, for each of the public sector spectrum users who attend UKSSC: description of current spectrum use; changes to be made to allocations; changes to spectrum management; and quantitative predictions and justifications for future spectrum needs.

2.10 Market intelligence

The Audit team commissioned a study into future commercial demand to ascertain the likely future pressure on the spectrum bands being examined. The study looked at the main 80 per cent of users, over the next ten years but also projecting to twenty years. The services examined were: cellular; terrestrial fixed links; satellite; fixed wireless access; and broadcasting. The results of the study were presented at a seminar held by the Audit team on 5th September, and are available on the Audit's website at www.spectrumbaudit.org.uk. They are summarised below.

Box 2: Demand study

The study looked at a base case macro scenario, combining likely outcomes for all services. This found that there could be a need for an additional 2.5GHz of spectrum below 15GHz by 2025.



Looking at services individually:

- **Cellular** - under a low traffic scenario, current/future planned spectrum allocations (including the 3G expansion band) should be sufficient to meet demand through to 2025. In a more aggressive high traffic scenario, however, there could be demand for an additional 0.8GHz of spectrum by 2025
- **Fixed-links** - Most of the growth will occur in bands above 15GHz – spectrum below 15GHz allocated to fixed-links should be sufficient overall. However, in the medium scenario, the 7.5GHz and 13GHz bands may run out of capacity in urban areas before 2010 and the 1.4GHz and 15GHz bands are projected to run out of capacity in urban areas by 2025
- **Broadband wireless access** - expected demand for an additional 0.2GHz of spectrum under the less aggressive scenario – this will primarily be in rural areas, but could also be required in certain localised urban hotspots. A more aggressive scenario could require up to an additional 2.5GHz of spectrum in urban areas and an additional 0.7GHz in rural areas by 2025
- **Satellite services** - additional spectrum requirements for mobile satellite services are modest – amounting to 0.3GHz in the most aggressive scenario. Broadcast satellite services could require significant increases to support the introduction of HDTV, leading to an additional requirement of between 0.6–2.3GHz of spectrum by 2025. Fixed satellite services will require an additional 0.9–2.8GHz of spectrum by 2025
- **Terrestrial television.** 0.4GHz of additional spectrum (over the 2012 post-DSO allocation of 112 MHz) could be required by 2014 in order to support a large increase in the number of digital terrestrial television channels and the widespread introduction of HDTV services.

2.11 Implications of demand study

The Audit team draws the following conclusions from the demand study:

- There is likely to be demand for spectrum which exceeds supply in the medium term.
- The precise nature of demand - frequency, bandwidth etc - and for what service will depend on a number of factors which cannot be predicted with any accuracy at this point. This supports the Audit's aim to put in place a more responsive, market based system for meeting future demands when they arise, rather than maintaining a command and control interventionist approach. The drawback of a command and control approach is that it involves making predictions of future developments and demand for spectrum, which are likely to turn out to be inaccurate. Seeking to claw back spectrum by regulatory means (and the threat of this happening) could itself cause delay to innovation and technology development, which is why the Audit is keen to restrict this route to exceptionalvarious means of sharing, for example in different geographic areas. The demand study flags up (as might have been expected) that urban demand is higher than that in rural areas. So there may be scope for example for the MoD to increase sharing on a time/geographical basis.

The Audit team found the demand study helpful in providing a basis for decisions about making spectrum available in the future. The Audit's view is that there would be merit in Ofcom carrying out such a review periodically.

Recommendation 2.7: Ofcom should build on the analysis done in the demand study commissioned by the Audit team, and take forward future work as appropriate to gather background information on likely future spectrum demand and market developments.

2.12 Information

The Audit's consultation document flagged up the importance of information provision to enable a functioning market. Consultation responses agreed. One of the difficulties in encouraging the public and commercial sectors to engage with each other, for example in negotiating sharing arrangements, or in the future to trade, is the lack of information about public sector usage of spectrum and the opportunities this might therefore offer for the commercial sector. The agreement of RSA will help with this process. In addition, the Audit is keen that public sector information, where possible, is made available as with information from the commercial sector.

Ofcom currently provide a Spectrum licensing portal¹⁰, which includes:

- The **UK Plan for Frequency Authorisation** (UK PFA) providing information about which frequencies are available for assignment, for what purposes the different frequencies have been allocated and whether these can be traded.
- The **Wireless Telegraphy Act Register** (WTR) provides basic information about individual licences such as contact names and address details, class of licence, band(s) of frequencies and where relevant

¹⁰ accessible through the Ofcom website (www.ofcom.org.uk)

geographic area of operation. At present information is limited to the classes that became tradable in December 2004.

- The **Transfer Notification Register** (TNR) displays details of proposed trades notified to Ofcom, trades in progress and completed trades.

Ofcom's main aim in providing this information is to encourage the development of the market. As the Audit is recommending that public sector spectrum can become part of the market, we are of the view that public sector spectrum trading information, as it becomes available in a suitable format (e.g. through RSA) should be incorporated into these public registers/databases. For example currently there are no details of spectrum holdings by Crown bodies in the WTR - information which will be needed to stimulate interest in trading.

Recommendation 2.8: Ofcom should seek to incorporate information about public sector spectrum usage and tradability in its public registers/databases.

2.13 Reviewing the effect of a market approach

As set out in this chapter, the Audit believes that the most effective and sustainable way of encouraging more effective use of spectrum by public bodies is to introduce market mechanisms into spectrum management of public sector spectrum. Public bodies have not previously been subject to pressures to make more effective use of their spectrum (other than that driven by their own needs or applied by fees). The measures in this report aim to introduce such pressure points. The approach outlined in this document is intended to create an incentive structure within which those best placed to know about their organisation's spectrum use can make decisions about how this is used in full knowledge of the costs and also the benefits of the options open to them.

This report sets out a series of actions to be taken to enable the public sector to engage with the spectrum market. If implemented, the Audit believes this will lead to an ongoing evaluation of public spectrum use which will in turn produce a more efficient use of spectrum as an integral part of planning processes. In doing this, the Audit is suggesting an enabling rather than compelling regime. However, it would seem sensible to review the effect of this approach in five years, when the policy recommendations have had time to bed down and the effect of a market approach on public sector use of spectrum can be assessed. To ensure neutrality, this review should be carried out by an independent party, but operate under the auspices of UKSSC as its customer (if the outcome is not as hoped, Government may wish to consider a more interventionist approach, perhaps creating an overarching spectrum management organisation for the public sector).

Recommendation 2.9: There should be a review of the impact of the introduction of market mechanisms on public sector spectrum management in five years. Ideally, this should be independently led, but working with UKSSC. If the effect of the introduction of market mechanisms is not as envisaged by this Audit, the Government may wish to consider implementing a more interventionist approach, for example setting up an overarching spectrum management organisation for the public sector.

Pricing

3.1 Introduction

The Audit's consultation set out the view that AIP (Administered Incentive Pricing) is an important mechanism for promoting enhanced spectrum efficiency in public sector spectrum use, but that there was scope for widening and refining its application and also a need for more development of the system over time, for example to ensure that market value is accurately reflected in pricing. The consultation also asked for views on possible alternatives to AIP including treating public spectrum as an asset subject to capital charges, relying on the incentive of tradability only, retaining activist command and control, or auctioning all spectrum in a 'big-bang' approach.

Most respondents to the consultation agreed with the core principle of applying spectrum pricing to the public sector although there were some concerns over the rationale and effects of extending pricing to aeronautical uses, and the limited evidence available on the effectiveness of AIP. One respondent questioned whether AIP remained a necessary and appropriate incentive once spectrum had been made tradable, and others suggested that there should remain a role for periodically assessing whether there was excess spectrum in the public sector and taking back any that was identified, on a command and control basis.

On the basis of current information, the Audit considers that AIP is likely to retain an important role in the public sector as market management of spectrum develops, not least for those bands where the opportunity to trade could remain limited. The Audit also recommends that pricing be extended to a wider range of spectrum uses, including radar and potentially other aeronautical spectrum in both military and civil use. AIP will be complemented by the introduction of tradability for public sector spectrum, especially where the level of pricing is a conservative estimate of the true value of the spectrum. Where tradability may be restricted, as with some aeronautical spectrum uses, the level of AIP and the way it is imposed and feeds through to decision-making and planning will remain critical to promoting efficiency. As with commercial spectrum, where trades take place of spectrum which is subject to AIP, the AIP will continue to be paid by the purchaser, whether public or commercial.

The Audit is not in favour of a 'command and control' interventionist approach whereby decisions are enforced on a one-off assessment, preferring instead to put in place an incentive regime that recognises the value of spectrum on an ongoing basis. Current opportunities for releasing or sharing spectrum are identified in the band specific Annex B of this report, which will be for the holders of the spectrum to take forward.

Recommendation 3.1: AIP (Administered Incentive Pricing) is, and is likely to remain, a fundamental element in recognising the value of public sector spectrum use and encouraging improved spectrum efficiency. AIP should be extended to a wider range of public sector spectrum bands and uses.

3.2 Consistency and future of AIP charges

As noted in our consultation there is currently a very large discrepancy between the pricing level applied to public sector bands badged for AIP purposes as 'fixed' and

'mobile'. Civil and military spectrum judged to be suitable for mobile use is charged at £240-396k per MHz depending on the rate of congestion. MoD bands where the alternative use is assessed as fixed services are charged at £2-3.9k/MHz for national use. There is no modifier applied to MoD fixed prices to reflect the higher value of lower bands, in contrast to commercial fixed bands where prices for links in lower bands have recently been raised. Examining the total AIP charges levied on individual users in the lower commercial fixed links bands (1.4 GHz, 4 GHz, Lower 6 GHz and Upper 6 GHz) reveals that they amount to a few thousand pounds per MHz. This is broadly in line with MoD fixed charges but far below the rate charged to mobile users in the lower parts of the spectrum. This 'cliff-edge' in rates does not provide a consistent reflection of spectrum values, especially as there is a moving boundary of the technological and commercial feasibility of different services. In addition, this approach of classifying bands by their fixed or mobile use is inconsistent with Ofcom's move towards technology and service neutrality.

There is also a large discrepancy in some bands between the pricing level for different fixed services and satellite users. A number of permanent satellite earth stations use the bands 3600 – 4200 MHz and 5850 – 6425 MHz. These earth stations are subject to AIP charges ranging between £15 per MHz and £36 per MHz (based on typical permanent earth station transmit bandwidths ranging between 36MHz and 575MHz). Looking at the effective areas that are denied to other services by individual earth stations, the overall level of pricing for these stations looks low in comparison to the charges on fixed wireless users in the same band, who pay approximately £5,000 per MHz for shared national use. However, it is recognised that the existence of a single earth station does not have any impact on the operation of other earth stations operating in close proximity. In fact, the only limitation to the number of earth stations that can be accommodated in a geographic area is the availability of satellite capacity. This is unlike the situation where a fixed service station (including FWA) creates a denial area for other stations of the FS as well as for earth stations. Ofcom is currently undertaking a review of the licence fees applied to satellite earth stations with a view to implementing the new AIP system already in place for fixed links.

We understand that Ofcom plans to review the values on which AIP fees are based periodically, beginning with mobile rates from 2007/8. Ofcom's intention to review the level of AIP every few years looks to be a fair balance between reflecting changing market conditions and providing stability for planning purposes. The Audit also supports Ofcom's intention to take revealed market values into account in revising AIP levels. The prospective extension of AIP to aeronautical and broadcasting spectrum (as suggested by this Audit and previous Ofcom spectrum pricing documents¹¹ respectively) will involve the useful addition of new sets of values to the AIP system. Ofcom's current policy is effectively that AIP levels for different services that could be competing for the same spectrum should gradually align through an iterative process.

In the longer term Ofcom intends to move towards a more generic per MHz pricing system which reflects the spectrum value curve and propagation characteristics, subject to any relevant restrictions (e.g. binding international harmonisation) but not based on the service-specific nature of the current use. The Audit supports this aim. In the Audit's view a pricing system that reflects a more appropriate 'spectrum value curve' through the most valuable bands and into spectrum with less favourable

¹¹ Ofcom Spectrum Pricing Consultation, September 2004, Section 8, http://www.ofcom.org.uk/consult/condocs/spec_pricing/spec_pricing/spec_pricing.pdf

propagation characteristics should be taken forward by Ofcom as soon as is practical.

Recommendation 3.2: When Ofcom next reviews the level of AIP the sharp distinction between the pricing of both public sector and commercial fixed and mobile services should be addressed. In the longer term Ofcom should move to a service-neutral per-MHz pricing system which reflects the spectrum value curve, subject to any relevant restrictions on use.

3.3 Formalising Public Sector Pricing

Currently spectrum fees are paid by Crown bodies to Ofcom by agreement, but Ofcom lacks a formal authorisation and pricing procedure. Public sector spectrum users that are not Crown bodies are already licensed on the same basis as commercial spectrum users, with appropriate costs applied, and we do not propose that this should be changed.

As set out in Chapter 2 the Audit is recommending the introduction of Recognised Spectrum Access (RSA) as the means to formalise the spectrum rights of Crown bodies, to recognise and formally to record existing spectrum usage, and potentially to enable trading of public spectrum. RSA will also be a means of formalising charging as Ofcom is permitted to charge for RSA – AIP is likely to be an appropriate basis for calculating such a cost.

However, the comprehensive application of RSA, enabling the formalisation of charging arrangements, is likely to take some time. During such time there are many changes to AIP suggested in this report which may come into effect. In order that Ofcom can implement such charges in a structured and equitable way, the Audit considers that it would be helpful if (i) a process for resolving any disputes over fees was agreed in case of need (in the Audit's view this could most appropriately be done through UKSSC); and (ii) Government bodies as a starting point should state their acceptance of the principle of paying AIP fees as determined by Ofcom, calculated on a comparable basis to the charges levied on the commercial sector.

Recommendation 3.3: To formalise the application and enforcement of AIP fees for spectrum held by Crown bodies, pricing should be attached to public RSA on the same basis as AIP pricing attaches to commercial WT licences. Until RSA are agreed, and in anticipation of the implementation of AIP changes recommended in this report, there should be a clear route for resolution of any disagreements over pricing levels (through the UKSSC structure). Government should also make a clear commitment to the principle of paying AIP charges on its spectrum holdings as requested by Ofcom, calculated on a comparable basis to commercial sector charges.

3.4 Pricing of shared spectrum

There is extensive sharing of spectrum between public and commercial users, and in some cases between different public sector uses e.g. emergency services use in defence bands. Sharing issues in general are dealt with in detail in the next chapter. The main public body which currently receives recognition of secondary sharing in its spectrum through reductions in AIP charges is the MoD, through set percentage reductions depending on the nature of sharing allowed. However if aeronautical spectrum pricing is introduced it will also be important to place appropriate incentives on both military and civil incumbent aeronautical users to permit bandsharing where it

can be done safely and will deliver an economic benefit, through appropriate recognition in pricing.

The Audit is keen that where a public body has admitted sharers into a band that it manages or occupies as a primary user, the financial benefit to the public body is as closely aligned to the value of the sharing enabled as possible. Options for reflecting the value of the secondary sharing include:

- **Direct payment:** The parameters and payment for secondary sharing would be agreed on a commercial basis between the primary user (e.g. MoD) and the party wishing to make secondary shared use of it. The primary user would still be subject to the full AIP charge for the band, as set by Ofcom. In some cases Ofcom may still need to provide a licence to a secondary party to authorise the use of spectrum if the secondary party is a non-Crown user.
- **Pricing Algorithm:** set by Ofcom in regulations as part of the prescribed licence fee. This approach could be suitable for shared use which could not easily be priced commensurate with its overall economic benefit (e.g. low-power devices or some PMSE use). Algorithms can also be appropriate for setting prices in bands with multiple users and might be a fair basis for agreeing prices where Ofcom still manages the sharing in MoD bands. This is the method currently used for Fixed Links – where pricing is calculated on a specific point to point basis, and PMR and PAMR, which are licensed and priced on a population coverage basis
- **Nationally apportioned charge:** The Audit's proposals for Aeronautical spectrum pricing advocate imposition of a national per MHz pricing on the industry for the overall value of its use, which would then be apportioned between the users of that spectrum by the regulating bodies (mainly Ofcom, CAA and MoD).
- **Agreed AIP Rebate:** This is the approach currently used for MoD-managed bands with secondary civil sharing. The MoD receives a rebate of generally 25% or 50% in its fees by agreement with Ofcom. Any revenues from the secondary use are collected by Ofcom through licence fees. This system does provide an incentive to the MoD to allow sharing but there are currently no established criteria for determining discounts and the size of the rebate is not directly linked to the value of the secondary sharing.

The Audit's preference is for the first model, where the primary user is responsible for paying the overall AIP fee for the band through licence (or RSA) fees, as set by Ofcom, and there is then direct payment by secondary sharers to the primary user at a rate to be determined commercially between the two parties. Further work is needed (which may be provided by Ofcom's work on the operation of band management) on whether there are legal difficulties with this arrangement for secondary use in a band shared between users who would hold a mix of RSA and licenses. If sub-licensing by the primary user is not possible then an alternative could be that Ofcom would knock off any receipts from the sharing commercial use from the public body's AIP.

Recommendation 3.4: In future sharing or leasing arrangements should preferably be managed by the primary user (or a third party acting on its behalf), who would also receive payment direct from the secondary user. Where Ofcom manages the secondary use through granting licences or RSA, fees set in regulations should be linked directly to Ofcom receipts from the

sharers, or to a sharing algorithm where that is not possible. The position on delegating charging functions should be clarified by Ofcom.

3.5 Partial MoD use

There are bands where the MoD is not the only major user but does retain geographically-restricted or occasional usage rights which limit the scope or reliability of civil operations. Where the current or future civil use is in spectrum to be auctioned the ongoing MoD use will affect the auction value (as will be the case in 412-414 and 422-424 MHz – see below). There are also MoD coordination and interference issues in the DECT guard bands and in other bands that Ofcom will want to auction in the short to medium term. MoD use in these bands should be defined by an RSA wherever possible.

In line with the principles above, the price paid by the MoD in these bands would ideally be directly linked to the effect of its use on the commercial market value of the band or by the proportion of areas or frequencies effectively sterilised. Where possible the MoD should manage the sharing arrangements directly and commercially with the primary spectrum holder as recommended above. Where this is not possible, for example because some of the details of the MoD use are restricted, Ofcom, MoD and the commercial users should agree a portion of the national AIP for the band to be paid by the MoD in recognition of their use. This sum would then be deducted from any AIP applied to commercial users in the band.

Where a public user only needs geographically-limited access to spectrum, e.g. for fixed links, the Audit and Ofcom agree that these needs should preferably be met through assignments in commercial shared bands.

Two examples of MoD use in bands identified for release in Ofcom's SFR:IP are:

- **412-414 and 422-424 MHz**: On 13th October 2005 Ofcom published a consultation on this band, which it intends to auction in spring 2006¹². A maximum 2x2 MHz of the wider 410-425 MHz band is earmarked for additional capacity for the emergency services and the remainder will continue to be used for defence purposes under MoD management. The commercial winner of the auctioned license will be required to clear any base stations with Ofcom in order to protect the Fylingdales military radar, and will be subject to geographical restrictions on deployment around other military sites. Ofcom has indicated that there could be scope for relocating these local military assignments in the band on a commercial basis, with MoD expecting the licensee to meet the costs. As it is difficult to estimate the impact that MoD use will have had on the auction value of the band the MoD fee for its use of this band should probably be a percentage of the full mobile rate AIP for the band.
- **1790-1798 MHz**: The restrictions caused by MoD use in this band are discussed in more detail in chapter 10. The MoD space operations in this band and restrictions on how much can be disclosed about their nature may impose constraints on auctioning this band when remaining emergency services fixed links are removed. In the Audit's view the MoD should pay AIP for their use of this band based on the level of constraint imposed on commercial use.

Recommendation 3.5: Where the MoD has partial use in a band used extensively for commercial services, the MoD should negotiate with and pay

¹² Available at: http://www.ofcom.org.uk/consult/condocs/spectrum_award/spectrum.pdf

charges to the primary user directly where possible. If this is not legally or practically feasible the MoD should pay for its use to the extent that it restricts the scope and value of commercial activity. The RSA should be classified if necessary, for use by Ofcom and MoD only.

3.6 Defence

The MoD currently pays £55m per year in spectrum fees, representing about 30% of Ofcom's regular income from AIP. Where the MoD pays AIP it is on a broadly comparable basis to commercial users. In the Audit's view AIP already plays an important role in recognising the value of the MoD's spectrum holdings and encouraging more effective spectrum management by the MoD. However we consider that there is scope for the system to be enhanced through extending AIP to the currently unpriced military spectrum uses outlined below, and by revisiting the level of pricing in other bands. As noted below there is currently an excessive differential between the pricing of fixed and mobile services, especially below 3GHz, which needs to be addressed.

The scope for the MoD to release spectrum is constrained in some bands, particularly those which are NATO-managed or harmonised. However in many cases the potential for alternative use has previously been demonstrated through the setting up of existing sharing arrangements and past release of spectrum from the MoD to the commercial sector. Annex B to this report identifies further possibilities for spectrum release or sharing which will need to be considered against the MoD's own future needs. The Audit considers that pricing all MoD bands on a comparable basis to civil spectrum imposes a greater level of certainty and more consistent incentives on the MoD to pursue opportunities for spectrum sharing or release. The main MoD spectrum use that would remain unpriced under the Audit's proposals would be some airborne uses which share spectrum with civil aviation. The following sections cover proposals for revising the charging regime applied to MoD spectrum use.

The changes proposed are likely to lead to a further significant increase in the MoD's AIP bill. Although the future prices of different bands will depend on final decisions made about the level and scope of pricing to be applied, on a rough estimate the MoD's AIP bill could increase to a level between two and four times the current total. As discussed later in this chapter there is an issue for the MoD and Treasury of how these increases will be handled.

3.7 NATO-Managed Band (225-400 MHz)

This band is managed directly by NATO rather than the UK and has not been charged for to date due to restrictions on the scope for unilateral action by the UK to convert to alternative civil use. Other bands in common use across NATO countries but managed nationally in the UK (such as 4.4–5 GHz, 8-8.4 GHz and 14.62-15.23 GHz) are already charged at the fixed rate.

The option of charging for the 225-400 MHz band has previously been considered, and Treasury and Ofcom intend to re-examine this at the time of the next Comprehensive Spending Review (which will conclude in 2007 and set budgets for the three years from 2008-09). The MoD has worked constructively with the Radiocommunications Agency and Ofcom to enable some commercial use at the margins of this band, including the use of 2x5MHz for the Airwave emergency service mobile system in 380-385 MHz and 390-395 MHz. The WT licences for the spectrum used by Airwave O2 Ltd are now subject to AIP (based on mobile values) whereas the surrounding spectrum still used exclusively by the MoD is not.

The Audit consultation document noted that any pricing decision should not be seen as penalising the MoD for showing flexibility and should include adequate discounts for the civil sharing that takes place. However, if pricing is not imposed this could give perverse incentives to the MoD as they would not benefit financially from any further spectrum sharing or release which they agreed to. The Audit acknowledges that the scope for releasing spectrum in the middle of this band is currently remote but there is also no clear or consistent means of determining some parts to be charged over others.

Having considered this issue further the Audit's view is that AIP should be imposed on the 225-400 MHz band, and that this should preferably be done in line with the timing of the next Spending Review. At the current mobile rate of £240,000 per MHz – which would seem to be the most appropriate rate given that it is used for most adjacent commercial bands - the charge for this band would be slightly below £40m after deducting spectrum used by Airwave O2 Ltd (380-385 MHz and 390-395 MHz) and TDAB services (225-230 MHz).

Recommendation 3.6 (i): AIP should be extended to the 225-400 MHz band at the standard 'mobile' rate with appropriate discounts for sharing included. This should be done at the next appropriate point in the budgeting cycle, probably the 2007 Comprehensive Spending Review.

3.8 MoD Radar Bands

Chapter 6 contains a detailed analysis of the case for applying AIP to radar, and suggests possible methodologies for doing so. There are two MoD bands classed as exclusively used for radar and not currently subject to AIP (on the basis that civil radar is also uncharged), **3.1-3.4 GHz and 5.3-5.65 GHz**. The MoD is already charged AIP on the standard basis for bands that have some radar applications mixed in with other defence use.

As the MoD is the predominant user, pricing of these bands should be on a national per MHz basis. As with other MoD bands, the pricing should preferably reflect what an alternative user could use the spectrum for. For both these bands the AIP level should take into account opportunity costs for radar and also other potential uses. On the existing AIP values the annual charge on the 3.1-3.4 GHz band would be about £1m at the 'fixed' rate or £72m at the 'mobile' rate, a very large discrepancy as discussed earlier. The 5.3-5.65 GHz band would cost £1.365m on the current 'fixed' basis.

Recommendation 3.6 (ii): AIP should be extended to the 3.1-3.4 GHz and 5.3-5.65 GHz military radar bands, charged on a national per-MHz basis. Pricing should be implemented on the same 2007-2009 timescale as for shared civil and military radar bands and on a comparable basis.

3.9 Bands below 3 GHz charged at the 'fixed' rate

The decision on how a given MoD band should be priced is made by considering the most likely alternative use. Broadly speaking lower MoD bands are 'mobile' and higher bands 'fixed' but four MoD bands below 3GHz are currently charged at the low 'fixed' rate of £3,000 per MHz (1375-1400 MHz, 1427-1452 MHz, 2025-2070 MHz and 2200-2245 MHz). Unlike civil fixed links there is no 'band factor' to reflect the higher value of lower bands in pricing of MoD fixed bands so spectrum at 1.5 GHz is subject to the same per MHz charge as if it was at 15 GHz.

For all the MoD bands below 3 GHz, if they were released now it is likely that the spectrum would be of significant interest, for example for mobile applications. It seems unlikely that they would be used for new fixed links. The Audit therefore considers that when the MoD's spectrum fees and the fixed/mobile differential are reviewed there is a good case for applying a mobile rate to all MoD spectrum below 3 GHz. If this was implemented at current rates it would increase the MoD's AIP bill for these bands by £28.44m from £360k to £28.8m. The longer term move to more representative pricing according to a spectrum value curve would address this problem, but in the meantime there is a case for changes to be made both below 3GHz as outlined here, and also to achieve a more gradual drop-off in pricing above 3 GHz.

Recommendation 3.6 (iii): The treatment of MoD bands below 3 GHz currently classed as 'fixed' should be reviewed to assess the case for pricing these at the 'mobile' rate instead.

3.10 Leased bands with an option to use in future

In the 3.4-3.6 GHz band the MoD agreed to Ofcom leasing out part of the band for 15 years to a commercial operator. MoD anticipates a future need for this band at the end of this period and under the terms of the agreement will need to make the case for this. The Audit considers that where a body agrees arrangements involving retaining 'options' on spectrum, there is merit in imposing a charge while this option is retained, both to clarify the body's rights and to encourage them not to retain options on specific spectrum unless there are clearly defined future needs.

3.11 Aeronautical

As detailed in Chapter 6 the audit is recommending the introduction of AIP for ground-based radar and its potential application to other ground-based or airborne systems where use could impose an opportunity cost. To date AIP has not been applied to aeronautical spectrum and if introduced in an appropriate manner it should help to improve the efficiency of spectrum use by aviation and potentially release spectrum for other uses. For those licence classes where AIP is not appropriate, pricing should remain at administrative cost-recovery levels for the moment (Ofcom are considering options including a fee free system for aircraft licensing).

In our view the introduction of aeronautical pricing should be achievable in the period 2007-09 and the Audit recommends that the Government response to this review sets out a timetable for implementation. It is not yet possible to indicate likely AIP levels as this will require analysis of the opportunity cost of current use to other aeronautical spectrum users. However, it is the Audit's view that it would be sensible to set prices conservatively initially, in line with previous practice in setting AIP.

The Audit is recommending that aeronautical AIP should be applied by setting national per-MHz charges, then apportioning these between the civil and military users in the band. We have advocated this system in preference to application of a set algorithm to each individual user as we believe it is a better mechanism for rationalising aeronautical use to the narrowest total bandwidth feasible, potentially enabling alternative use for other services. In some cases the scope for national autonomy will be limited by international coordination and obligations – in these cases it is also sensible to have a coordinating body in a position to push for changes at an international level.

3.12 Maritime

Most maritime spectrum fees are currently cost-based. Chapter 7 sets out the Audit's proposals for maritime pricing in more detail, recommending that there is a case for introducing Administered Incentive Pricing in some licence classes, including Navigational Aids and radar. Licences not recommended for AIP application would remain cost-based. Ofcom are currently working towards implementing lifetime licences for some of these licence classes.

Some maritime pricing is already set on a comparative basis to Business Radio using the same bands, and this should continue to be kept under review. However, work on developing on other maritime pricing such as navigation aids and radar should be taken forward in parallel with aeronautical pricing, especially where the two services share the same spectrum on a geographical basis as in the 2.9-3.1 GHz band. The Audit is also recommending that the MCA should be a member of the new UKSSC radar and aeronautical subgroup as coordination with maritime radar users will be required.

3.13 Public Safety Services

The mobile systems used by the emergency services, including the network provided by Airwave O2 Ltd, are charged at the standard commercial mobile rates. As set out in Chapter 8, Ofcom expect to administratively assign part of the 410-425 MHz band to provide additional capacity for emergency services. This spectrum is initially being charged at the standard mobile AIP rate but the Audit supports Ofcom's intention to revisit the level of pricing of the new emergency services spectrum in the light of the market value revealed by the auction of the adjacent band.

3.14 Other uses

There are also transport uses of the spectrum, partly with a public safety element and which in some cases, e.g. Transport for London, currently share or are looking to share public safety services spectrum. Transport users, plus other local and national public sector spectrum users who do not have a direct public safety remit, generally pay for their spectrum on the same basis as other commercial users in these bands.

3.15 Funding Spectrum Charges

AIP will have no effect on the efficiency of spectrum use in the public sector if any increase in charges is automatically compensated for by a higher budgetary allocation. However, in the Audit's view it is appropriate in some circumstances that cost pressures arising from an increase in the level or coverage of AIP caused by factors outwith a Department's control (e.g. those one-off changes being suggested by our Audit) should be recognised in setting budgets at the time of the CSR.

3.16 Reviewing AIP

A number of respondents to our consultation noted a lack of evidence on the effectiveness of AIP. Having considered possible alternatives discussed in our consultation, we endorse the principle of AIP as a tool. We do not see a feasible or better pricing mechanism for promoting efficiency in the use of spectrum that has not been auctioned. There is anecdotal evidence that pricing has had a positive impact on public spectrum management, for instance through the MoD giving up spectrum bands when subject to steep increases in pricing. Where the impact of AIP will be in

affecting major planning and procurement decisions, results may largely be seen in the medium to long term.

Given the importance of AIP in spectrum management (a role endorsed and expanded by the recommendations in this Audit), the Audit is of the view that it is important that the regular reviews of AIP rates carried out by Ofcom are thorough and well informed. It is important in terms of efficient spectrum management that the application and levels of AIP are applied consistently and in line with the market value of spectrum. The recommendations outlined here should go some way to addressing this, but Ofcom should also seek to keep itself informed about revealed market values as the trading environment develops, and use this information accordingly. In addition, Ofcom should keep the application of AIP under review to ensure that it is effective, that this can be demonstrated in future and that proper evaluation of the impact of AIP and changes made to it are an integral part of the regular AIP review process.

Recommendation 3.7: We endorse the principle of AIP. To ensure the effectiveness of AIP as a tool, the periodic reviews of AIP rates should be informed by (i) market value of the spectrum being taken into account in AIP application and level; and (ii) reviewing the impact of AIP.

Bandsharing

4.1 Introduction

Spectrum is a finite resource and, as demonstrated by the demand study carried out for the Audit (see Chapter 2 for a summary of findings) demand is likely to exceed supply in the medium to long term in the bands the Audit is examining. Opportunities for making more effective use of spectrum by sharing it between users – for example on a spatial, temporal or geographical basis, or by using technology to enable services to coexist - are therefore an attractive proposition if this allows multiple demands to be satisfied simultaneously.

This chapter covers two approaches to increasing sharing opportunities. Firstly, sharing arrangements are already in place in many of the bands the Audit is examining. The Audit's aim is to encourage public bodies to consider allowing more of these tried and tested methods of sharing, for example by making sure that pricing for bands accurately reflects the value of sharing allowed. Secondly, the Audit is interested in whether any new technological opportunities could open up possibilities for sharing between services and in bands not previously considered. This chapter sets out some of the barriers to these opportunities being developed, how these barriers might be addressed and where there might be a case for action by Government or the regulator in doing this.

4.2 Pricing for sharing

Currently, where a body such as the MoD pays AIP on a band and allows other uses into the band on a shared basis, this attracts a rebate on the AIP charges. This rebate is a flat rate of either 25 or 50 per cent depending on the nature of sharing. As set out in the Audit's consultation document, sharing rebates would ideally reflect the value of sharing allowed more closely. Chapter 3 on pricing sets out the Audit's preferred option of pricing for shared use, whereby the primary user is responsible for the whole band charge and then agrees secondary use and associated charging arrangements directly with the secondary user. Other options where this might not be possible include giving rebates of different percentages and charging according to a pricing algorithm.

4.3 Defining sharing arrangements

Sharing arrangements in public sector spectrum bands are often ill defined, having been agreed bilaterally and then managed as necessary over time. While these arrangements have often worked well, this informal system of sharing will not be sustainable in the future. As trading and liberalisation leads to greater variation and flexibility in the use of spectrum it will become even more important to have certainty and clarity about the use of bands and the agreements in place between coexisting or adjacent users. The Audit is keen that the move to market management of spectrum does not lead to a reduction in the level of sharing permitted in public sector bands due to concerns from the bodies about the risk to their operations of increased interference or lack of ongoing certainty about usage. Equally it is important that these bodies are able to gain certainty and transparency about the nature of coexistence arrangements (both past and future). The Audit is recommending that RSA be introduced for Crown bodies (see Chapter 2 for more

details about this proposal, and how RSA are likely to be formulated). This will provide a tool for codifying sharing arrangements and the costs attached to those. In support of the development of RSA including sharing arrangements, the Audit recommends that the NFPG undertake work to codify existing sharing arrangements, which can then be enshrined in the RSA.

Recommendation 4.1: In parallel to the work to establish RSA for Crown bodies, the NFPG should agree and codify existing sharing arrangements, beginning with the priority bands for RSA. These agreements could then be annexed to the relevant RSA.

4.4 Third Party

The Audit's consultation document suggested that there might be merit in the creation of a third party intermediary to deal with the commercial side of public sector spectrum engagement with the market, which the Audit is keen to encourage but which public bodies themselves might not yet have the resources or expertise to fully undertake. Respondents to the consultation were largely supportive of this idea, as long as it did not simply mean an additional layer of bureaucracy in spectrum management.

Such a body would have a role in facilitating trading agreements as well as sharing arrangements and is therefore also relevant to Chapter 2 on market mechanisms. The Audit's conception of such a body is that it should be initially 'pump-primed' funded from the Spectrum Efficiency Scheme for a limited period of 18 months, to assist public sector spectrum users in spectrum trading and sharing agreements (seeking market opportunities at the behest of the public body and brokering agreements).

Public bodies might also want to use such a body for other functions – for example to provide assistance in monitoring spectrum usage, defining rights or establishing charging arrangements. Such roles (set out in more detail below) would be optional for the public body, and should therefore be funded separately by the bodies themselves where they chose to contract for such services, over and above the SES-funded call-off contract.

4.5 Funding routes

The Audit considered various options for funding such a body. Ultimately, it will be for the beneficiaries from such a function to pay for it – this will be a mixture of the public bodies themselves where they are able to generate income, commercial companies gaining access through such a mechanism and possibly the body itself if it works at risk and takes a share of the profits. However, it is recognised that in the short term the benefits of such a body may not be clear to the public sector (or possible commercial beneficiaries) and that, in the interests of promoting efficient spectrum management, there is therefore likely to be merit in funding being provided to get the Third Party scheme off the ground, funded for an initial 18 month period. At the end of this period SES funding should end and it will be up to the bodies concerned to choose whether to continue to fund such a function.

The Audit's preferred set up for the Third Party is therefore as follows:

1. A 'pilot' project funded by the Spectrum Efficiency scheme for a set period of time (18 months is suggested). Ofcom would procure a third party on behalf of these organisations and pay for the set up costs and a retainer

for the agreed period, through the SES. Services paid for by the SES would be facilitating (i) trades and (ii) sharing arrangements on a basic level – i.e. the body dictates the band and provides information on use and the third party seeks market opportunities and carries out the transaction (not actually holding the spectrum ‘rights’ at any point). These services would be performed on behalf of and at the behest of public bodies – defined here as the attendees of the UK Spectrum Strategy Committee who manage spectrum (which includes the Ministry of Defence, Civil Aviation Authority, Maritime and Coastguard Agency and sponsor departments for the Emergency Services)

2. If the public bodies wanted expanded services they could pay for them (e.g. if a more in depth survey of intensity of use across bands was required to set up a database from which to trade from). Of course, it is hoped there would be some income from trading/sharing arrangements to enable them to do this
3. Some form of profit sharing between the third party and public body. To incorporate an element of the third party acting at risk, but also as a sign of commitment by the public body
4. After the initial pilot period it would be for the public bodies to decide whether to keep funding the services of the third party. It would make sense for a discussion of this to be held at UKSSC and for UKSSC to act collectively if there was agreement to this, but equally there should be nothing stopping bodies contracting separately if they wished

Possible roles for the third party were set out in the consultation document and are expanded upon here. The first two bullets are the basic functions provided for by SES funding, the others are additional functions such a body could provide on a contractual basis to the public bodies.

- **Facilitating trades**, including on a short-term basis. This would be a key role of any Third Party. The Audit recognises that public sector bodies are not generally set up and resourced to deal with commercial transactions, and the availability of commercial assistance could encourage the use of market mechanisms in the public sector where otherwise the bodies involved might be reluctant to act. The third party would be able to address possible market failure caused by public bodies not knowing the market signals to act on, for example by providing market knowledge and identifying market opportunities.
- **Negotiating specifics of sharing arrangements**, through a database or directly in more detail for more complex arrangements. This could include pre-emption arrangements where needed. As above, outside assistance could encourage bodies to engage in more of this activity, encouraging more effective use of spectrum. The third party would need to be able to deal with sensitive information on the security and safety side, and have spectrum management experience. The suggestion is not that this body would deal with actually testing, or writing standards for new bandsharing techniques or technologies. That role would be covered by the new sharing sub-committee of UKSSC proposed below. The role of the body described here would be to facilitate specific sharing arrangements (which may be based on standards/parameters already set by the sub-committee) including charging agreements. From the public sector point of view, there would be a single entity with which they would take up any problems encountered during, or changes required to, sharing. This function could, in support of the NFIG work and that of the new Sharing sub-committee (see below):

- In the first instance, take a role in defining existing sharing arrangements between public bodies where needed. If there was a need for actively managing these arrangements, or overseeing charging arrangements (see below) this body could take on that responsibility.
- Facilitate and agree new sharing arrangements between incumbents and new entrants, including agreeing sharing parameters and costs
- **Band manager.** More in-depth spectrum management, including making and managing assignments and interference. This sort of role might be valuable where there is a multiplicity of users with benefits to be derived from coordinating their spectrum management.
 - For example in the case of the Emergency Services where there may be benefit in a coordinating body managing spectrum (see Chapter 8 for details).
 - In the case of the MoD, the department could make a decision to utilise such a body to manage intra-department spectrum usage if resource constraints prevent this being done internally.
- **Information** collection about spectrum allocations and usage. This sort of information is likely to be needed by Ofcom and the public bodies themselves to agree Recognised Spectrum Access parameters, and later to facilitate trades. It does not necessarily have to be done by a Third Party but resource constraints elsewhere could make this an attractive option. There are various ways this could be done:
 - Through collating and publishing information about use
 - The third party acting as a repository for information (which is possibly not suitable for publication e.g. for security reasons) and then responding to requests about use
 - Setting up a system with this information whereby new requirements could be judged against existing use automatically. Such a tool could model this information in a way that when requirements were keyed in for new use, a yes/no answer would be produced based on the system information but without disclosing it.
- **Monitoring** of usage over time, perhaps building up a picture of use and therefore highlighting areas of low intensity/no use. Such information could be used to facilitate sharing, either through simple time sharing methods, or more dynamic management methods.
- Administering a **charging regime** for sharing, collecting charges from users to benefit the organisation permitting this use. Again, an optional role which would be more appropriately funded by the body itself if it saw merit in this.
- Ofcom may wish to take into account **spectrum values** revealed by the work of the Third Party to inform revisions of AIP rates.

The above roles are all to be carried out at the instigation of the public body. An alternative (more interventionist) model, which could be considered at the five year review point if the market mechanisms approach does not seem to be working, would be for a body to act at the behest of Government/Ofcom as a 'band manager' for public sector spectrum, administering the AIP regime and actively seeking market opportunities for use of spectrum managed by public bodies. The Audit is not in favour of this interventionist approach at this stage. It is intended that the market

based spectrum management framework suggested in this Audit should instead place public bodies in a position where they themselves make the best use of their spectrum (as they are best placed to know what their spectrum requirements are and to manage these), whether for their own operations or through releasing it for other use (perhaps for financial benefit).

In all cases apart from the 'band manager' bullet above, the public sector body would retain their spectrum rights and the intermediary would act on their behalf (the third party would not at any point own or hold spectrum rights)

We have discussed the concept of such a body with potential customers, who are supportive of the idea. The Ministry of Defence is likely to be one of the main users of such a function and has undertaken to engage productively with the third party during its pilot phase, and to evaluate the success of such a resource for their department at the end of the pilot period.

Recommendation 4.2: A third party body should be set up to act as an intermediary between public bodies and commercial interests. This should be funded from the Spectrum Efficiency Scheme for a pilot period of 18 months to provide free facilitation of trading and sharing arrangements for public bodies (with an element of profit-sharing built in).

4.6 Technology

Developments in technology, for example digital techniques, improved filtering and improvements in basic manufacturing techniques, have already made it possible to use – and reuse – spectrum more efficiently. Previous bandsharing studies, for example those done for CEPT SE34, were based on simulations from which it was difficult to assess safety case issues. In addition, current Spectrum Efficiency Scheme studies into Cognitive Radio, increasing the power of licence exempt devices, systems above 60GHz and mesh radio may also produce relevant conclusions.

The Audit commissioned studies from Roke Manor and QinetiQ to ascertain current and future technology developments with the potential to open up new and innovative forms of bandsharing. The remit of these studies was to encompass the range of spectrum being examined by the Audit, but with a focus on the radar bands, particularly 2.7-3.4GHz, given the significant bandwidth occupied here, by a relatively small number of users¹³ and in a valuable area of the spectrum given the potential alternative use. Public versions of both studies can be found on the Audit's website and a summary of the headline messages from the studies are given in the box below.

¹³ The emphasis has been on the military and aeronautical use of the 2.7 to 3.4 GHz band with consideration being given to maritime radar requirements. The number of maritime, magnetron based radars approaches 5 million world wide, most of which could theoretically end up in UK ports at some time. Maritime radars have not been the lead systems in the studies conducted during the Cave Audit period, however it is possible that there are similar bandsharing opportunities in maritime bands which could be investigated in the future, and these systems would need to be included in any testing in radar bands in which they operate.

Box 3: Headline messages from bandsharing reports

Qinetiq

- Focus of report is on 2.7-3.5GHz, but most of the concepts and techniques are applicable throughout the radio spectrum.
- Suggests an approach to bandsharing which encompasses both freeing of spectrum through radar efficiency gains, and simultaneous co-channel occupancy by multiple services through use of adaptive systems.
- QinetiQ have experimented using a surveillance monitor to provide intelligence to network configured software, which enabled a high powered air surveillance radar and a simple low-power communications network to operate in close proximity (~100 meters) of each other.
- Further work is suggested to build on this initial finding that coexistence is possible (but the suggestion is that the technologies profiled in the report could be realisable within a five year timeframe).
- Other suggestions include use of a real-time spectrum trading model using temporal, geographic and frequency sharing opportunities.

Roke

- Identified a cellular communications system as the best candidate for sharing with radar.
- Suggested two approaches with a longer (10-20 year) timeframe for implementation:
 1. integrated sharing, creating a new infrastructure meeting the needs of both radar and communication services together through using communications transmissions as the radar pulse. Range disparities between the two systems caused problems with this approach;
 2. spatial sharing – overlaid spectral re-use patterns with carefully managed interactions between the two - communications cells assigned frequencies which exclude those in use by neighbouring radars. Ad hoc exclusion zones are recommended as a possible way of accommodating military requirements. Under this system, initial estimates suggest that over 50 per cent of the radar spectrum could be available for sharing in this way.
- Again, further work was suggested by Roke to fully assess the feasibility of the second idea.

4.7 Realising technological possibilities

The Audit concludes from the reports that there are significant technological possibilities - including those included in the studies outlined above - which could enable forms of bandsharing to be brought into commercial operation in the medium to long term – or indeed to be used by the incumbent users to enable more effective use of their own bands and equipment. However, as both reports point out, there are a number of issues to be addressed before these technologies could be introduced in the UK.

4.8 Testing

The current occupiers of the 2.7-3.4GHz band operate safety and security critical services, and will require high levels of assurance that the introduction of new technologies and services into this band would not compromise operation. There will therefore be significant and stringent testing requirements to satisfy before a new bandsharing method could be admitted. Given the potential spectrum efficiency gains which could be realised if a suitable technology could be brought into operation, the Audit feels that there would be merit in Ofcom facilitating this test programme and funding a proportion of it through providing test facilities. Equally, given the potential commercial benefit if such technology was brought into operation – and we understand that there is commercial interest in such an option - those making use of the facilities should also contribute to the cost through an attendance fee, so taking on some of the ‘risk’ associated with trialling new methods like this, which may of course not prove to be operationally practicable.

The specification for the test programme should be discussed and agreed with the incumbents of the band – MoD, CAA and MCA – through the Spectrum Safety Test Group (PSSTG) group¹⁴ to ensure it meets their requirements for permitting sharing in the band. These bodies should also be involved in the test programme itself and provide reasonable help – perhaps through contributing equipment for use in testing. **The Audit recommends that once PSSTG requirements have been agreed, and the testing programme underway, there should be a presumption in favour of sharing being admitted with any technology meeting these criteria.**

The test programme should be agreed and announced for set dates in the future, with an open invitation for technology companies and manufacturers to participate. If the testing programme reveals specific technology barriers to a promising technique being introduced, Ofcom should consider whether this merits further research funding from the Spectrum Efficiency Scheme to address these problems.

Recommendation 4.3: MoD, CAA, MCA and Ofcom should agree a specification for a test programme to be carried out on the use of bandsharing technologies to allow sharing between radars and communications systems. Once PSSTG requirements have been agreed, and the testing programme is underway, there should be a presumption in favour of sharing being admitted with any technology meeting these criteria. Ofcom should facilitate the test programme, providing testing capabilities; the incumbents should provide reasonable help as necessary. If the testing programme reveals specific technology barriers to a promising technique being introduced, Ofcom should consider whether this merits further research funding from the Spectrum Efficiency Scheme to address these problems.

4.9 Test bed

To expedite the testing regime which is agreed, it would be helpful to have access to the key band being examined - 2.7-3.4 GHz – for testing purposes on a more permanent basis than that provided by a test and development licence. This could be achieved by CAA and MoD identifying spectrum to be made available for sharing trials, on a spatial or time basis – for example in areas of the country where interference to radar systems would be less problematic or for periods of time where

¹⁴ The Public Spectrum Safety Test Group is the regulators forum for MoD, MCA, CAA and Ofcom, joined by NATS in a pseudo-regulatory role, to discuss testing requirements, identify safety case issues and advise the Ofcom testing programme

radar operation is not required, taking into account the need to maintain their operational requirements.

Recommendation 4.4: CAA and MoD should make spectrum available for sharing trials in the 2.7-3.4GHz band on a spatial or time basis.

4.10 Regulation/standardisation

For effective bandsharing to be introduced, agreement needs to be reached between the new entrants and incumbents on parameters and performance characteristics such as the maximum level of cumulative interference that can be received by primary radar. A testing programme is needed, as above, to effectively 'type approve' any proposed systems. As long as the technology meets these interference limits, it could then be used in accordance with agreed operating conditions.

Manufacturers and other interested parties may wish to formalise the agreed maximum emission limits through developing standards through the appropriate European and international bodies. For example, it would be possible to produce a UK standard against which manufacturers could produce equipment, using the characterisation of the devices and parameters (power, bandwidth, spurious emissions etc) resulting from the testing regime. This would probably begin with the definition of a generic standard for the band, enabling a range of protocols and technologies to be used with equipment specific standards subsequently overlaid.

However, in the longer term, and to maximise the commercial potential of this technology, manufacturers and other interested parties may additionally decide to pursue a European and/or international route to standardisation.

There would need to be a concerted and thought-through approach to pursuing regulatory issues, involving all interested parties. This process would need to be initiated and led by industry, with Ofcom involved where intervention by the spectrum regulator is likely to be necessary in implementing the standard. To initiate this process and bring interested parties together, Ofcom have offered to hold a meeting with key industry stakeholders to discuss the outcome of the testing programme and possible next steps to bring any promising technology into operation. It would then be for industry to take any subsequent work forward.

The next WRC is due to take place in 2007, and the parties involved in considering new sharing technologies should consider the possibility of seeking to secure a discussion on sharing at this forum in order to bring the debate to an international level, potentially leading to new sharing studies. The agenda item dealing with aeronautical spectrum may provide such an opportunity.

4.11 Assessing sharing possibilities

Decisions on sharing issues, including the possibility of admitting new sharers/technologies into a band, are currently made on an ad hoc basis. The PSSTG was formed to consider safety and testing issues, but this is focused specifically on technical safety and compatibility issues rather than sharing issues in general.

The Audit's view, and a suggestion made in a previous report carried out for Ofcom¹⁵ is that there would be merit in creating a high level group to discuss bandsharing issues including Ofcom, MoD, CAA and MCA. This group would focus on issues relating to setting overall safety/security/testing/parameters of sharing (as opposed to negotiating individual agreements, which would be for the incumbents or possibly the third party intermediary mentioned earlier in this chapter). PSSTG could feed into the workings of this group where relevant. This group could have responsibility for coordinating overall sharing arrangements, including between public sector bodies themselves, acting as a single contact point and for reaching common agreement on any changes to public shared bands.

Opening agenda items for the group could include a discussion of issues raised elsewhere in this chapter:

1. the possibility of establishing a 'test bed' for sharing in the radar bands;
2. what form the testing regime for proposed bandsharing technologies should take, including defining the protection standards necessary to satisfy safety and security requirements;
3. interaction with an independent third party to facilitate bandsharing;
4. the bandsharing agenda at a European and International level;
5. consider harmonised parameters and operational conditions that could be applied to shared bands (current or future)

This group could form a sub-group of UKSSC. It is suggested that the members themselves could elect a Chair for the group.

Recommendation 4.5: A bandsharing group consisting of Ofcom, MoD, CAA and MCA should be established. Issues are suggested for early consideration by the group. The group should form a sub-group of the formal UKSSC structure.

4.12 Test and Development Licences

The consultation document asked for views on the effectiveness of the current T&D licence regime and how this might be improved, and for views from existing users on how much flexibility here would be considered reasonable. There was little response to this question, but one respondent suggested that a review of the operation of T&D licences would be a good idea. Ofcom is planning to review the operation of T&D, looking both at the current system and how it meets the needs of stakeholders and how this regime relates to the longer term agenda set out by the Spectrum Framework Review.

The Audit is content that this issue should be progressed through the reviews planned by Ofcom, and would ask that the review work bear in mind the concerns of the Audit team as set out in the Audit's consultation document: that the T&D regime should encourage innovation, should not be adversely affected by the introduction of trading and liberalisation; and that access to as wide a range of bands as possible should be facilitated in this way.

¹⁵ *Assessment of the technical, regulatory and socio-economic constraints and feasibility of the implementation of more spectrally efficient radiocommunications techniques and technology within the aeronautical and maritime communities available at <http://www.ofcom.org.uk/research/technology/other/sss/ay4620/?a=87101>*

4.13 Audit aim

In the interests of making efficient use of spectrum, the Audit is of the view that bandsharing holds significant potential in terms of increasing possible use. As outlined above, the Audit is recommending ways to encourage existing sharing methods to be expanded upon and used more. There also appears to be merit in exploring some of the more exciting technological possibilities which may enable new forms of bandsharing to be brought into operation, either for use by commercial operators sharing with incumbents or indeed by the existing users who may wish to make more effective use of their own bands and equipment.

Given the safety and security concerns in one of the target bands – radars in 2.7-3.4GHz – which it is necessary to satisfy, and which may inhibit commercial interest in development, coupled with the need to protect use in adjacent states, the Audit is recommending a role for Government and the regulator in part-funding and carrying out tests and initiating regulatory action. Beyond the initial satisfaction of safety and security concerns, however, it will be for commercial funding to bring such technology into use, in part through agreeing appropriate sharing arrangements with the incumbents.

Ministry of Defence

5.1 Introduction

The Ministry of Defence (MoD) is the single largest user of spectrum in the UK (managing, or with a significant interest in, around a third of the spectrum the Audit is examining). The Audit's consultation document set out a number of areas of interest with regards to MoD's spectrum management - predominantly how much the department pays for its spectrum and how these costs are managed and policy coordinated internally; how spectrum requirements are taken account of in the procurement process; how the MoD interacts with other users and the use of some specific MoD bands. This chapter concludes that the MoD themselves have made positive progress through the drawing up of their spectrum policy, and makes recommendations to strengthen and widen the action being taken in a number of areas.

5.2 Pricing

Chapter 3 covers the Audit's detailed proposals on extending Administered Incentive Pricing (AIP) for the MoD. In summary, the Audit's recommendations as a whole would lead to a significant increase in the MoD's spectrum fees. The Audit considers that its proposals are necessary in order to ensure that the value of spectrum held by the MoD is realised and the appropriate incentives put in place to encourage this use to be made more effective. The Audit does however realise that there is an affordability issue with the increases proposed, and sets out in Chapter 3 its view on meeting these charges.

5.3 Band specific

The Audit's consultation document set out a number of bands to be examined for scope for release to alternative use or for admitting sharers. The conclusions from this examination can be found in annex B of this report. Assessments are made for each band, based on the information available and an examination of the scale, scope and nature of services in a band. Judgements are made on the potential for all or part of a band to be shared, released, or that there is merit in other action being taken in the band (e.g. the application of pricing, which is covered in detail in chapter 3).

The detailed annex should be read in conjunction with this chapter. In summary:

- International constraints have in some cases precluded possibilities being identified, at least in the short term, or mean that any action possible may be limited to the UK
- Timescales for changes being made vary depending on the need for further action to be taken before change is possible
- In the majority of bands examined, it is the Audit's view that there is potential for release or further sharing. These judgements have been made for a variety of reasons:
 - Information about the type and number of services in the band indicating that it should be possible for spectrum to be made available for sharing or release;

- Information about the nature of use (intensity; area and frequency of use) indicating that there should be scope for geographical or time sharing;
- Technological developments which may have the potential for introducing new sharing techniques;
- Where there is a band shared with another user and it appears that services could be better coordinated and planned to enable additional alternative use;
- Where there is a mixture of services, possibilities for better planning and/or consolidation/rationalisation of existing use) are highlighted.

The Audit notes that the MoD will need to consider its own future needs before making final decisions on the use of bands going forward, and it is recognised that in some cases future uses for a band may not as yet have been identified and quantified. It is for this reason – that bodies themselves are best placed to know their spectrum usage and future needs – that the Audit recommends that an incentive regime be created – leading to more effective management of spectrum - rather than dictating what action is most appropriate in each band. MoD is currently undertaking its own work to benchmark current, and scenario plan for future, spectrum use. We hope that the assessment in this report is a helpful input into that process, and suggest that these work strands can be usefully be brought together in the UKSSC Forward Look document.

Recommendation 5.1: MoD should report, in the UKSSC Forward Look document on its future plans for management of its spectrum holdings in the light of the Audit’s band specific analysis and its own current benchmarking and future scenario planning work.

5.4 MoD spectrum policy

The MoD are currently working on a new Spectrum Policy. This was prompted in part by the first Cave Review, which commented on MoD’s information and coordination structures, and has since evolved into a policy to address the pressures on MoD spectrum to accommodate new requirements, for example to use Network Enabled Capabilities in the UK for contingency operations, development and training whilst managing interference. The policy recognises that there is a direct relationship between available bandwidth and military capability and estimates that for MoD “bandwidth requirements have grown ten-fold over the past decade and will increase further...”.

The Audit welcomes the new policy, which covers many of the areas noted as issues for MoD spectrum management in our consultation document. The Audit is aware that the main driver behind this change of MoD policy is to increase warfighting capability, but will restrict its comments to those aspects affecting UK spectrum use where the Audit feels that there is scope for improvement/refinement. The implementation of the policy going forward will be crucial to addressing these issues, and this section sets out the Audit’s view on the central elements of the policy. To ensure that implementation is proceeding as planned, the Audit is of the view that the MoD should report on progress against the strategy as part of the first Public Spectrum Forward Look which the Audit is recommending be produced through UKSSC (see Chapter 2). It is recognised that those areas targeted for change will be implemented in stages and over a period of transition.

Recommendation 5.2: MoD should report to UKSSC on progress in implementing its spectrum policy in the first Public Spectrum Forward Look. In particular, attention should be paid to the areas highlighted in this report.

5.5 Target setting

The Audit's consultation document suggested that setting targets relating to MoD's use of spectrum could be a useful tool. The Audit's preferred approach is for the MoD to face sufficient incentives through income retention arrangements to adopt a rigorous approach to the use of their spectrum. However, it is recognised that take-up of the incentives systems being put in place is wholly voluntary. If it proves in time that the new spectrum management regime proposed in this report has not had the desired effect of raising awareness of spectrum as a valuable resource to be managed effectively within the department, HM Treasury may wish to consider setting a target for MoD's spectrum management.

The Audit suggests that the timing of the Comprehensive Spending review, which will set new budgets and targets for the three years beginning 2008-09, provides a suitable opportunity for addressing this issue and judging MoD's progress against the Audit's recommendations.

Recommendation 5.3: Setting spectrum targets should be considered further in discussions between MoD and HM Treasury in the context of the 2007 Comprehensive Spending Review, when overall targets will be revised.

The nature of any target would need to avoid skewing the incentives intended to make more efficient use of spectrum, and also take into account possible future needs of the MoD itself. A target could for example cover one of the following:

- Percentage of spectrum identified to be released over a time period
- Increased level of sharing (measured for example on number of agreements, or MHz shared)
- Income generated from spectrum management activities (e.g. through trading, sharing arrangements, short term leases etc)

5.6 Coordination

The Audit team are pleased that the MoD policy identifies the need for spectrum requirements and coordination to have a raised profile within the organisation and to have a senior lead within the department. To this end MoD plan that:

- The Spectrum Acquisition Authority (see below) will be chaired by the director¹⁶ with oversight of equipment capability for Information, Surveillance, Targeting and Reconnaissance (DEC ISTAR)
- DEC ISTAR will have a core DEC responsibility for spectrum across all the MoD equipment capability areas which will provide significantly improved coherence on spectrum issues.
- A Spectrum Joint User Working Group will formalise the linkages between those in MoD who are customers of the central MoD unit dealing with spectrum management. This should for example identify opportunities for more dynamic sharing arrangements to be agreed within MoD as this group will include all front line commands.

¹⁶ MoD directors are military One Star appointments or civilian equivalent. It is at this level that the MoD is represented on the UKSSC.

The success of the policy and therefore progress in important areas e.g. in taking spectrum requirements into account at a sufficiently early stage, will depend on the collaboration and cooperation of the many stakeholders identified in the policy and the development of new linkages and relationships.

We think it is important that the MoD develop an implementation plan tied to delivery of the policy, with clear timescales attached to each aim and responsibility for delivery identified and agreed to.

Recommendation 5.4: The MoD should produce an implementation plan for delivery of its spectrum policy with respect to spectrum in the UK, including timescales and responsibilities clearly identified and allocated.

5.7 Procurement

As outlined in the Audit's consultation document, the Audit is of the view that more account needs to be taken of spectrum requirements in the procurement process to ensure that spectrum needs are identified at a sufficiently early stage to identify appropriate bands and factor in the costs of use of these into equipment decisions. We are therefore pleased to see that the MoD spectrum policy includes the creation of a Spectrum Acquisition Authority (SAA). The SAA will consider the spectrum requirements of new equipment when the specification is in genesis, and before money has been allocated or a contract placed. The SAA will take responsibility for ensuring that a whole life spectrum cost is factored into the decision making process.

The Audit team is of the view that the SAA as conceived could work effectively to:

- Ensure that spectrum needs are identified at an early stage in defining equipment requirements
- Estimate the cost of the spectrum required and factor this into the decision making process
- Provide an overarching, coordinating body to take a holistic view of spectrum availability and future requirements

The Audit is keen that the Terms of Reference for the SAA reflects these roles. A first step in this process would be for the SAA to make a change to the overall acquisition process to require that spectrum is considered as an input as standard– the Audit recommends that this option is considered.

If the SAA structure works as suggested and spectrum costs are highlighted at a sufficiently early stage, then we can see the benefits of maintaining the centralised responsibility for the costs of spectrum, rather than cascading fees to users. A review of the operation of the SAA should be included as part of the update on progress against the strategy mentioned above, reporting to UKSSC. At this point a decision should be made about whether responsibility for meeting spectrum fees should be disaggregated within MoD (for example with those responsible for NATO operations meeting the costs for those bands required for essential NATO commitments), or continue to be met centrally. If the latter, transfer of this responsibility to the SAA should be considered. The SAA should also consider, and assign responsibility for, overseeing the assessment of commercial opportunities for MoD spectrum.

Recommendation 5.5: The Audit recommends, with regards to the SAA, that: (i) its Terms of Reference encompass the roles envisaged in Chapter 5; (ii) the SAA consider amending acquisition requirements to include spectrum as an

input for consideration; (iii) the operation of the SAA is reviewed after one year and reported on in the Public Spectrum Forward Look document; (iv) at this stage a decision should be made whether spectrum fees should be transferred to the SAA for management or disaggregated within the Department; and (v) the SAA allocate responsibility for oversight of the assessment of commercial opportunities for MoD spectrum.

5.8 Dynamic spectrum management, research & technology

The majority of MoD spectrum holdings are currently managed on a 'static' basis – that is through permanent assignments. In a battlespace situation, however (predominantly outside the UK), 'dynamic spectrum management' is becoming the norm, necessitated by the need for multiple systems to operate at the same time in the same geographical area. There are also examples of specific MoD bands being managed more dynamically, for example datalink 16, an airborne command and control system which is planned centrally by the RAF around fixed CAA assets in collaboration with continental airforces, under rules agreed with the CAA. This type of dynamic management relies on discussion and agreement of use on a case by case basis. Dynamic spectrum management can cover anything from this type of slower time/manual management on a case-by-case basis to more sophisticated techniques e.g. using software to manage spectrum access. Different techniques may be needed for different bands depending on the services and technologies in use and interoperating.

The MoD themselves recognise that the current arrangement of permanently assigning frequencies to formations and systems could be improved upon by a more dynamic system where spectrum is reused where terrain screening or separation allows and reassigned when not in use. This will require a more flexible approach, appropriate management tools and flexible equipment. The MoD currently plan to consider applying dynamic spectrum management to each band individually as and when a need arises for increased use of that band and if appropriate tools are developed to enable this.

The Audit team considers that there would be considerable benefit in dynamic spectrum management being considered for all of the MoD spectrum holdings, (recognising that the conclusion may be that some bands may not be suitable for dynamic management to be applied). This would have benefit not only for MoD (in improving the efficiency of use of their own bands and enabling training in a more realistic 'battlespace' environment) but may also have a wider benefit through increasing the potential for admitting sharers through dynamic management. For example, the demand study carried out for the Audit highlighted that there are likely to be increasing demands for spectrum on a geographical basis in the future – such sharing might be attractive to the MOD and suit the nature of its spectrum usage.

Given the wider benefit this could bring, the Audit considers that it would be a valid use for Spectrum Efficiency Scheme funds to part-fund, with the MoD, a study into the system(s) needed to introduce dynamic spectrum management into all suitable MoD bands. We estimate that this could be done for around £200k and would look for a contribution from MoD research budgets to part-fund this. Once systems had been scoped out, funding for bringing them into operation could either be provided by MoD themselves, seeking commercial gain, or commercial interests who would like to share MoD bands.

Recommendation 5.6: Spectrum Efficiency Scheme funds should be made available to part fund, with the MoD, research into systems to enable MoD

bands to be more dynamically managed and to increase sharing possibilities. Ofcom and the MoD should agree on a joint budget and specification for this work and manage the project together.

5.9 Battlespace Spectrum Management

Battlespace Spectrum Management (BSM) can be seen as one form of dynamic spectrum management, and probably the most developed to date. A pilot system currently underway uses software to map the requirements of defined equipment in a given environment against each other, producing a battlespace spectrum management plan of frequency assignments. MoD intends to develop this system so that it includes a greater depth of spectrum engineering, for example considering out of band emissions. MoD sees that, once developed, aspects of this system could potentially be applied to UK spectrum bands in peacetime. This model should therefore be included in the dynamic spectrum management capability research project recommended above.

5.10 Current & future use

The Audit's assessment of current and potential future use of key MoD spectrum bands is detailed in the band specific annex of this report. The Audit team are grateful to MoD's central spectrum management team for their cooperation in providing information and discussing use. However, through the process of seeking and discussing information it has become apparent that the MoD does not currently have a comprehensive picture of either their current use of spectrum or likely future requirements. We are therefore pleased to see that their spectrum policy includes plans to produce baseline information on current and future requirements (the latter through developing scenarios). This information will also be needed to feed into the revised procurement processes, as covered above, and the UKSSC's forward strategy, as mentioned in Chapter 2, and should be a key element reported on in the annual report on progress in implementing MoD's policy, as mentioned above.

The MoD may wish to make use of the assistance to be provided by the third party intermediary (the establishment of which is covered in chapter 4) in collating, or subsequently using this information to maximise use of MoD spectrum holdings, including by considering MoD future use of its bands.

5.11 Resourcing

The Audit team is grateful for the assistance provided to the project by the MoD's Defence Spectrum Management team. Through the Audit process it has become apparent that the resources devoted to spectrum management in MoD have been allocated on the basis of a passive spectrum management role, largely maintaining the status quo. As the Audit (and indeed the MoD's own spectrum policy plans) recommends a much more active role for the MoD in managing their spectrum resources, it is clear that resources will need to be increased accordingly.

Recommendation 5.7: The Audit recommends that MoD should review its resource allocation to spectrum management in the light of the more active spectrum management role recommended by this Audit and envisaged in the MoD's spectrum policy document.

The MoD policy also includes proposals for increasing spectrum awareness and training amongst staff, which the Audit supports.

Aeronautical

6.1 Introduction

The Audit's consultation document indicated our support for introducing AIP to aeronautical spectrum use in principle:

“The Audit considers that designing and implementing a system of aeronautical radar pricing could provide an important mechanism for helping to deliver more efficient spectrum use. However there are a number of complexities around which types of radar this could in practice be applied to in the short to medium term, how any system should be designed and how the level of prices should be determined to give an effective and fair incentive to make better use of the radar and navigation aid bands.”

We received consultation responses from both aeronautical spectrum users and companies interested in accessing the spectrum. Views expressed included the following:

- Radar Pricing – responses from existing radar users and manufacturers were generally against the idea. Others agreed with the general principle that AIP should be applied more consistently across the spectrum. Better coordination of aeronautical bands and regulatory action to support adoption of improved systems was suggested as preferable by existing users.
- Sharing – There was general interest in expanding sharing opportunities as long as sufficient testing is carried out to ensure that safety and security-critical services are protected. There were some comments that developments in radio technology could enable dynamic sharing rather than exclusive bands to become the norm, and that spectrum policy development should reflect this possibility. There was also further interest in the possibilities for sharing in the radar bands following the Audit's 5th September where QinetiQ and Roke Manor outlined their reports for the Audit, covering possible technical solutions for radar bandsharing.

In the Audit's view there is a strong case for introducing pricing to those aeronautical spectrum uses, principally radar, where current use imposes an opportunity cost. This chapter sets out that it will be necessary to evaluate the opportunity cost of spectrum to aeronautical users before AIP can be extended to these spectrum users. Hence we are not able to provide concrete assessments on the level of pricing. It will be for the managers of the spectrum and Government to take forward the Audit's recommendations on aeronautical spectrum management and pricing. In doing so it will of course be vital to ensure that this process does not compromise safety imperatives or unduly disadvantage the UK aviation industry. As noted in the consultation there is a strong international dimension to aeronautical spectrum policy and allocation. For this reason and due to the scale of re-planning and re-equipment that would be required to release spectrum in most cases, the benefits of pricing and other Audit recommendations in this area are likely to be seen in the medium-long term.

A flowchart illustrating proposals on the applicability and structure of AIP for aeronautical systems is attached at Annex E.

Recommendation 6.1: AIP should be extended to military and civil aeronautical uses of the spectrum where it has the potential to help increase efficiency of spectrum use now or in the medium to long term. Beneficial effects of pricing could include:

- ***Maximising the benefits to aviation of its existing spectrum holdings***
- ***Recognising and enabling other potential uses of the spectrum (where alternative use would be possible)***

This chapter also sets out the Audit's recommendation for formalising the arrangements for joint CAA and MoD coordination of shared radar and aeronautical bands through a new subgroup of the UK Spectrum Strategy Committee. This group would also be responsible for apportioning pricing in joint civil/military bands. The chapter in this report on bandsharing and the studies we commissioned from QinetiQ and Roke Manor are also highly relevant to the aeronautical spectrum.

6.2 Band specific

A detailed assessment of the use of selected radar and aeronautical bands is given in Annex B of this report. Most aeronautical and maritime bands are shared between civil and military use, and details of the range and scale of services in a band are given based on available information. Judgements are made on the potential for change in two categories. The first is the potential for all or part of the band to be released or for additional sharing to be enabled. The second is the scope for 'other action', largely the introduction of pricing. The Audit's recommendations on the applicability of pricing by band are set out later in this chapter, with the basis for these decisions given in Annex C.

Annex B should be read in conjunction with this chapter and Annex C. In summary:

- In the majority of the bands examined the Audit's view is that there is scope for some release or additional sharing of spectrum, over different timescales depending on the nature of current use, procurement cycles and international constraints.
- Some possibilities for alternative use of spectrum on a UK-only basis have been identified. However in other bands where it appears technically possible to reduce aeronautical spectrum allocations, reuse by other services will only be possible in practice following internationally agreed changes.
- The Audit is recommending the application of AIP to a range of aeronautical bands. In several of these bands the 'other action' column is marked as amber rather than green because the design and implementation of the pricing system will take more than a year.
- Where a band is relatively lightly used or services are duplicated or spread widely across the spectrum, possibilities for rationalising allocations, better planning and improved coordination with other services are highlighted.

The Audit notes that the scope for reuse of spectrum for other services will depend both on the scale and nature of future demand from aviation and on international spectrum policy decisions. The introduction of pricing and potentially tradability should encourage the users and regulators of the spectrum to take forward opportunities to enhance overall efficiency of use, directly through the market and where appropriate through international fora, but there may also be a role for

regulatory action. We suggest that progress against the opportunities identified in the band-specific audit is reviewed in the UKSSC Forward Look document, alongside a commentary on future needs.

Recommendation 6.2: CAA and MoD should report their future plans for management of aeronautical spectrum holdings in the UKSSC Forward Look document, including progress on the opportunities for spectrum release or additional sharing identified in the Audit's band specific analysis (see Annex B). Plans for shared civil/military bands should be coordinated through the new radar and aeronautical subgroup of UKSSC.

6.3 Potential Benefits of Aeronautical Pricing

The potential benefits of AIP, to other aviation users or other services, lie in making users aware of the cost of their use of spectrum which they had previously not paid for. Where there are international constraints careful consideration is needed of whether the spectrum could realistically be used for alternative services if the aeronautical use was reduced or removed. The two main classes of potential benefits are:

1) Recognising the value to aeronautical spectrum users of their holdings through encouraging:

- a) Use of more spectrally efficient equipment
- b) Reductions in unwanted emissions
- c) More intensive use of aeronautical bands through better co-ordination and removing excessive frequency or service diversity
- d) A market-based means of accommodating growth in aviation spectrum demand

2) Recognising and enabling other potential uses of the spectrum through:

- a) Releasing spectrum for alternative uses
- b) Imposing discipline on requests and uptake of new aeronautical spectrum
- c) Encouraging bandsharing in aeronautical spectrum

6.4 Setting the Level of Aeronautical AIP

AIP fees are designed to equal the marginal value of spectrum based on its opportunity cost and are set in relation to both the value of the spectrum in existing uses and its value in other potential uses for each band.

The CAA and MoD have historically managed aeronautical spectrum with the assumption that in general they had to meet any changes in demand within their existing spectrum resources. Excess demand was not revealed in market prices for the resource, but actions such as tightening of equipment standards have been used to alleviate any shortages. Excess demand could include military use being constrained by the scale of civil presence in shared bands, or vice-versa, although it would be difficult to attach an exact value to this.

1) Calculating the value to other Aeronautical Users: As the value of aviation spectrum use is not part of the current AIP structure and calculations and assignment of aeronautical frequencies has not historically been subject to market signals it is difficult to estimate the opportunity cost for aviation services without further work. **Ofcom will need to carry out a study in conjunction with CAA to estimate opportunity cost to aviation users themselves to enable the introduction of AIP for radar and other aeronautical services.**

For the purpose of setting AIP the marginal values are calculated by estimating the minimum additional cost (or cost saving) to an average or reasonably efficient user as a result of being denied access to a small amount of spectrum (or being given access to an additional small amount of spectrum) and using an alternative which may include:

- **Investing in more/less network infrastructure to achieve the same quantity and quality of output with less/more spectrum:** We have not identified any clear opportunities to do this in aeronautical or other radar uses.
- **Adopting narrower bandwidth equipment:** The report relating to Aeronautical and Maritime Spectrum Efficiency¹⁷ and recent Spectrum Efficiency Scheme (SES) projects, including on spectrally efficient radars¹⁸, will help to provide values here.
- **Switching to an alternative band, service or technology:** There is limited scope for providing aeronautical radar, navigation aid or communications services through alternative technologies (e.g. there cannot be a fixed line substitute). However there may be scope for substituting different bands and systems (e.g. shifting radar from UHF to L-Band, or switching to MLS from ILS). In other cases if a radar use was withdrawn (e.g. removal of an airfield radar) the cost would be the flights and associated activity foregone. In the longer-term there may even be a move away from the use of primary ATC radar.

An opportunity cost will be estimated if assessment of the factors above shows that there is excess demand from other potential aeronautical users. If there is not, then the opportunity cost to alternative aviation users is effectively zero (in any bands where this was the case AIP could only be imposed on the basis of an opportunity cost to alternative users).

2) Calculating the value to Alternative Services: If the existing AIP system reflects true opportunity cost, adoption of the same base level for setting AIP as adjacent (non-aeronautical) bands should make aeronautical spectrum users take full account of the demands of alternative potential users and release spectrum for re-use where this is feasible and delivers a net economic benefit.

The obvious existing reference levels for the value of aeronautical spectrum to alternative services are therefore the national mobile (£240-396k per MHz) and fixed (£2-3.9k per MHz) prices. As discussed in Chapter 3, in the Audit's view a reassessment of the 'fixed' or 'mobile' opportunity cost values needs to be conducted in advance or parallel to the calculation and introduction of AIP to aviation or maritime spectrum. Ofcom may also want to take market values revealed in upcoming spectrum auctions into account.

If there is judged to be no prospect of alternative use due to international restrictions and since the UK is unable to act unilaterally in spectrum that is internationally harmonised for on-board use, then the opportunity cost of the spectrum for alternative use should be judged to be zero.

¹⁷ <http://www.ofcom.org.uk/research/technology/other/sss/ay4620/ay4620.pdf>

¹⁸ Spectrally Efficient Radar Systems in the L and S Bands, Ofcom research project (ongoing), <http://www.ofcom.org.uk/research/technology/overview/ese/sers/>

6.5 Initial Pricing Level

Ofcom is rolling out an amended methodology for AIP, which sets fees towards the bottom of the range defined by the value of spectrum in existing uses and its value in alternative uses. We understand that Ofcom plans to review the values on which fees are based periodically, beginning with mobile rates from 2007/8 and fixed services after that, which will enable fees to be adjusted towards the equilibrium level by an iterative process.

This approach of setting initial pricing levels conservatively looks appropriate for aeronautical AIP due to likely uncertainties about the true opportunity cost (especially to alternative aeronautical users in the absence of trading or auction information) and the potential economic and political cost of setting prices too high. In line with Ofcom's standard principles for applying AIP, where there is the potential for national flexibility the initial AIP should be set slightly above the aviation opportunity cost if there is a higher value alternative use, or at the aviation opportunity cost if it is judged that aviation is in fact the highest value use. In the latter case this could argue for revision in the AIP for the alternative service.

Recommendation 6.3: Initial AIP charges should be set conservatively, in line with Ofcom policy for other AIP classes. As part of this process Ofcom will need to evaluate the opportunity cost of existing aeronautical spectrum use to an aviation user denied or granted spectrum use at the margins.

6.6 Limitations of UK pricing regime

One reason why AIP has not been implemented for aeronautical services to date is that there is extensive international harmonisation in aeronautical allocations due to the need for robust regulation and coordination to meet minimum safety parameters. Spectrum for aeronautical use is designated by the ITU and in order to achieve global inter-operability, equipment standards and frequency planning criteria are harmonised through ICAO, which requires compliance with published Standards and Recommended Practices (SARPs).

However, the overall responsibility for spectrum and frequency management remains a matter for national Governments. In general there is significantly more scope for national decisions and variance from international norms in ground-based primary functions than those involving communication with aircraft or with internationally-mobile aircraft using radionavigation spectrum. The Audit accepts that there are some services where national reuse is not possible. But there are circumstances where it may be achievable and use should be priced as such.

The benefits of pricing and potential value of released aeronautical spectrum would be higher if the introduction of market mechanism and greater flexibility of spectrum were taken forward at an EU or international rather than national level, and consequently the Audit encourages Ofcom and the CAA to promote this agenda internationally. If an AIP system is introduced which calculates separate opportunity costs for aeronautical bands and other adjacent services, their relative level could be used to inform the UK position for ITU decisions on whether to make new internationally harmonised allocations for aviation.

6.7 Coordinating and Apportioning Charges

Where a band is shared between multiple users who each have fixed allocations, as in the L, S, X and Ku band radar, individual stations clearly deny a potential opportunity to others due to the protection distances required, and there is usually scope for national reuse. There are different options for how pricing could be imposed, which will be suitable for different conditions:

A: National per MHz Band Charge: This is the most appropriate system where there is one user. The holder of the spectrum should be encouraged to make as full use as possible of spectrum they continue to hold while releasing clear spectrum for reuse where possible. This is the approach used for the MoD bands that are already subject to AIP and we recommend it should be extended to the exclusive military radar bands (3.1-3.4 GHz and 5.3-5.65 GHz).

B: Pricing individual users according to an algorithm: This would price spectrum according to parameters including bandwidth, coverage (linked to power) and a spectrum value unit. This is similar to the pricing model applied to fixed links, PMR and PAMR and has merits for multiple fixed ground-based users. A downside to this model, as discussed in Chapter 10, is that it does not directly encourage the packing of aeronautical use into the minimum necessary total bandwidth or the release of underutilised spectrum.

A variant of this model would be to include 'impact supplements', in a parallel with the algorithm proposed for radio astronomy. These could be used for example where a band is designated for radar but lightly used, and the limited radar use places disproportionate restrictions on the scope for reusing the band for alternative services. Where there is extensive scope for geographical sharing by other services, for example by fixed links away from X-Band or Ku-Band radar, a standard area-based algorithm is appropriate.

C: Imposition of national band charge. CAA to co-ordinate and apportion charges to individual users: Subject to maintaining required performance and safety standards, the additional benefits of national 'per MHz' pricing divided between users could be to:

- Reduce geographical and frequency separation of installations where feasible
- Encourage more consistently intensive use of radar bands in places of sparse occupation, e.g. at the margins of bands
- Give a more proactive role for the CAA as the band planner and put pressure on partly used bands, encouraging either intensive use or disposal.

D: Pricing remains at cost-recovery levels or use is licence-free: In most cases *airborne* spectrum use is less suited to incentive pricing as either:

- Individual users impose no clear limitation on use by others (e.g. radio altimeters). There is no limit on the number of aircraft licences issued and there is no direct spectrum management. The only realistic means of improving spectrum efficiency is through international regulatory action
- The same frequencies are used internationally and aircraft from different jurisdictions use UK airspace, making national implementation of narrower channels or bands difficult.

- The audit understands that cost-recovery licences do not currently always very accurately cover the true licensing costs, and where this is the case the pricing structure should be reviewed.

As a general principle where use is shared the aim is to incentivise individual users to take decisions which improve overall economic benefits from the spectrum. However in most aeronautical bands it will only be possible to make a major step forward in spectrum efficiency with co-ordinated action taken with the involvement of the sector regulator. It would also be difficult to enable increased sharing in radar bands and cascade the benefits to individual spectrum users without regulator involvement. In bands which are primarily aeronautical but contain other non-aeronautical services (e.g. GNSS, radio amateurs, etc.) Ofcom would need to ensure that the level of pricing imposed on the aeronautical sector fairly reflected their share of use in the band.

Where national apportioning between service types is not feasible, individual ground installations should be charged according to a pricing algorithm. This may be in cases where the band is only partially used by radar and there are other uses which are either airborne and would not be suitable for pricing, or are non-aeronautical uses.

Recommendation 6.4: As co-ordination between the regulator and individual users will generally be needed to enable redeployment of aeronautical spectrum, where possible pricing should be imposed as an overall per-MHz band price. It would then be the responsibility of a co-ordinating body to apportion the band price and work with users to enhance intensity of use or release spectrum. Algorithms which reflect impact on other spectrum users should be employed where this is not feasible (or desirable if it could create perverse incentives).

Recommendation 6.5: For other airborne uses where the opportunity cost is effectively zero and there is no direct spectrum management pricing should remain at cost-recovery levels for the moment (Ofcom are considering options including a fee free system for aircraft licensing). Currently cost-recovery licences do not always very accurately cover the true licensing costs, and where this is the case the pricing structure should be reviewed.

6.8 Application of pricing to specific bands

Further detail on the suitability of different spectrum bands and uses for pricing is given in Annex C (Annexes C and E of the consultation document also summarised the aeronautical bands and their main uses). The Audit's recommendations for the scope of pricing are:

Recommendation 6.6: AIP should be introduced on the basis of both the value to aeronautical users and potential alternative users in all ground-based radar systems:

- ***UHF Radar (subject to a potential spectrum clearance project)***
- ***L-Band***
- ***S-Band***
- ***X-Band***
- ***Ku-Band***

Recommendation 6.7: There may be a case for pricing DME ground stations, since they are licensed with discrete and potentially scarce assignments. The case is not clear-cut but Ofcom should assess the case for pricing DME as part of the exercise in determining the scope and level of aeronautical AIP to be implemented.

Recommendation 6.8: The MLS allocation is currently underused and there may be a case for applying pricing to this spectrum on the same basis as ground-based radar sites. This is subject to a concern that disproportionate pricing on initial users should not discourage the adoption of a more effective technology, and potential pricing of MLS should be linked to a review of navigation aids and landing systems as below.

Recommendation 6.9: There may be an economic case for differential pricing of ground-based and/or airborne VHF communications licences to accelerate adoption of more spectrally efficient equipment in congested spectrum. Ofcom should investigate the opportunities further, in conjunction with CAA.

As detailed in Chapter 3, the Audit also recommends that the bands with exclusive military radar use (3.1-3.4 GHz and 5.3-5.65 GHz) should be priced on a national per MHz basis. Pricing should be implemented on the same timescale as for shared civil and military radar bands and on a comparable basis.

There are a range of aeronautical allocations below VHF, including HF Comms and non-directional beacons, which may not all be intensively used. Due to very long range propagation and a general absence of clear scarcity or high value alternative use the Audit's view is that this spectrum is not currently a priority for pricing or other steps to improve efficiency of use.

Chapter 7 sets out the Audit's view on application of pricing to maritime systems. It would be appropriate to take forward the aeronautical and maritime pricing agendas for coastal ground stations in parallel.

6.9 Review of Navigation Aids and Landing Systems

There are currently a wide range of systems used in aviation which perform similar functions but require multiple spectrum allocations. There are three main landing systems available, ILS (instrument landing system), MLS (microwave landing system) and GBAS (ground-based augmentation system), and a range of different navigation aids and beacons are used. There is some requirement for multiple systems and redundancy to provide a fallback and meet stringent safety standards. It is also standard practice for frequencies for different systems to be paired, which can cause inefficiencies (e.g. While an airport may use Channel G for VOR, DME and ILS, a single VOR which did not have paired services could deny use of the paired DME or ILS channels over a wide area). However it appears that the range of service allocations is greater than technically required and duplication can persist for long periods as the adoption of a new system tends to be followed only very slowly by the phasing out of forerunners.

The Audit therefore considers that a review of navigation aids and landing systems should be carried out by the UK to identify the scope for rationalising systems and/or spectrum allocations. This review will need to be led by Ofcom and CAA with MoD involvement. Its recommendations should include the role of a UK spectrum pricing regime and an action plan for achieving coordinated international action, which will be key to achieving the potential economic benefits of rationalising these systems.

Recommendation 6.10: Ofcom, CAA and MoD should undertake a joint review of navigation aids and landing systems to consider whether any rationalisation of multiple allocations is feasible. The opportunities identified should be pursued through pressing for changes at a regional or global level, and through the use of market mechanisms where possible.

6.10 UHF Radar (590-598 MHz)

The Audit's consultation document noted that there was diminished and currently very low usage of a radar allocation in this band, and that there might be a case for clearance of this use. In principle there is an argument for using pricing, even the imposition of a full national price, for this spectrum to incentivise the current users to move vacate the band.

Following further discussion, we understand that the incumbents would be open to discussion about a compensated move out of this band. The CAA has confirmed that they are happy to facilitate such discussions. This will need to take place in the context of the wider discussions about broadcasting spectrum being taken forward at the 2006 Regional Radio Conference in order to assess the costs and benefits of such a move and therefore determine the case for a funded clearance project. It is likely that clearance proposals or an overlay auction will be a more timely option for clearing this band than pricing.

Recommendation 6.11: Ofcom, with assistance from the CAA, should take forward discussions with the incumbents of the 590-598MHz band with a view to vacating the band (including the option of a funded clearance project). These discussions should take place in the context of the wider debate on broadcasting spectrum in RRC06 in order to properly assess the costs and benefits of such action.

6.11 Unwanted Emissions

Unwanted emissions (out of band and spurious) from radars can have significant effects on the quality of spectrum outside the core operational band of the radar which is used by other operators or services. In the Audit's view there is a strong case for further research into how these externalities could be recognised and reduced through the use of market mechanisms as well as regulatory changes. Unwanted emissions are a particular problem with radars due to their high peak powers, but can also be an issue with other high-power transmissions such as broadcasting.

The UK has previously been at the forefront in pushing for international decisions and regulations which promote improved spectrum efficiency. However it is understood that this process is moving slowly due to those who wish to see no change. The Audit encourages the UK to take the lead in encouraging further research and international regulations to better define, recognise and ultimately reduce unwanted emissions, seeking to involve those from industry and academia who are in favour of change.

Recommendation 6.12: Radars tend to produce significant levels of unwanted emissions which can adversely affect the intensity of use and hence value of other spectrum bands. The Audit considers that there is an economic case for taking account of these negative externalities through a system of penalties on radar users for the degradation they cause to spectrum use in other bands.

Further research and proposals on this issue should be taken forward by Ofcom in parallel with the extension of AIP to radar.

6.12 Implementation of Aeronautical Pricing

The 2002 Cave Review recommended that a pricing regime for UK-based radionavigation and radiolocation equipment should be developed and phased in over five to seven years. Ofcom and its predecessor the Radiocommunications Agency have undertaken technical studies on the scope for improved efficiency in spectrum use by the aeronautical and maritime sectors, but there have been no decisions on pricing to date. In our view it is important that there is some clarity on the next steps following the Audit.

Pricing should preferably be taken forward in parallel with trading. Ofcom has stated its intention to make a decision on the feasibility of trading for ground based aviation and maritime coastal communication uses by 2007 and that in the radio navigation licence class, trading of rights of use would be introduced between 2007 and 2009. The scope for trading by individual aeronautical licensees is likely to be limited, but the release, trading or sharing of spectrum might be possible with coordinated action. If such trading occurs there could be a role for the new radar and aeronautical subgroup of UKSSC in facilitating trades. Civil aviation users are already licensed and these licenses could be made tradable. The Audit is recommending the use of RSA to formalise other public sector spectrum uses, including military. The rights built into licences and RSA, including Ofcom's plans for the introduction of Spectrum Usage Rights, will also be important to ensuring that trading and liberalisation in adjacent bands do not have an adverse effect on the safe operation of aviation.

In the Audit's view it should be possible to take forward aeronautical pricing on the same timescale as the implementation of trading, which fits with the dates envisaged by the 2002 Cave Review. It will be for Ofcom to design, consult on and implement an aeronautical pricing system, setting the overall level of fees in consultation with interested parties and in line with the principles set out here. CAA have made provision in the NATS price control to recognise the introduction of AIP, including by recouping any fees already paid during the next price control period if necessary.

Recommendation 6.13: As part of their response to this Audit, Government, Ofcom and the CAA should jointly adopt and publish a timetable for consulting on and implementing AIP for appropriate aeronautical spectrum classes. In the Audit's view implementation of AIP could realistically take place in line with Ofcom's plan to introduce trading in appropriate aeronautical licence classes between 2007 and 2009.

6.13 Management of Civil-Military Sharing

The introduction of AIP will enhance the role of CAA in managing civil aeronautical spectrum through agreeing the overall level of charging with Ofcom, apportioning charges between different users in shared bands and overseeing the co-ordinated action that is likely to be required to free up or share significant quantities of spectrum. The CAA will still need to coordinate any changes with neighbouring countries.

Most of the major aeronautical bands are shared between civil and military use and the two sectors require coordination. The sharing between civil and military operations is often complex and although some Memoranda of Understanding are in place, the current system is relatively ad-hoc. In some cases (e.g. fixed ground-

based ATC radars) military and civil systems are essentially substitutes in the same frequencies, but there are also other military systems that may have very different mobility and transmission characteristics to the main civil users.

The Audit's consultation document suggested that the arrangements for joint CAA and MoD coordination of shared radar bands should be formalised, including the possibility of using a joint planning tool. We continue to favour this approach, and think this could be achieved by constituting a new group with a remit to:

- Apportion fees between individual users and collect them (in line with the Audit's preferred pricing model)
- Take decisions on competing demands for spectrum
- Manage detailed compatibility and planning
- Use a joint planning tool to enable more efficient and dynamic assignment

This group could be constituted as a subgroup of the UK Spectrum Strategy Committee (UKSSC) with a membership of Ofcom, CAA, MoD, DfT and MCA, and it would build on existing arrangements for coordinating shared bands. Contentious or major public policy decisions could be referred up to the main UKSSC committee for decision. A separate subgroup for aeronautical coordination and pricing could have the benefit of allowing full membership for the regulators and the opportunity for more detailed planning work.

The pricing model for these bands would be a version of Option C – National per MHz band divided among users – with discounts to the fees to be applied where the band incorporated sharers of a type to which AIP was not applied. Producing a workable model to allocate cost of shared bands between civil and military users is related to the wider need to better define the MoD's protection and transmission rights, possibly through RSA, so that military and civil use can be fairly apportioned.

Recommendation 6.14: The arrangements for joint CAA and MoD coordination of aeronautical bands should be formalised, perhaps including the use of a joint planning tool. A new radar and aeronautical subgroup of UKSSC should be constituted with a membership of Ofcom, CAA, DfT and MCA. This group could be established in 2006, in advance of the introduction of AIP. Its eventual remit would be to:

- ***Apportion fees between individual users and collect them***
- ***Take decisions on competing demands for spectrum***
- ***Manage detailed compatibility and planning***
- ***Use a joint planning tool to enable more efficient and dynamic assignment***

6.14 Future of Aeronautical Licensing

Licensing of aeronautical spectrum is currently administered by the CAA on a contract from Ofcom¹⁹. In addition to a proposal to issue free lifetime licences to all ship radio users, Ofcom are considering the possibilities for reducing the regulatory burden of the aeronautical/aircraft licensing process and are minded to make changes to the current regime, although some form of licensing will need to be retained. As noted in our consultation document the Audit is concerned to ensure that this process does not have any negative unintended consequences such as precluding the introduction of AIP in spectrum where it could deliver economic benefits. Therefore in the Audit's view **significant changes to aircraft licensing**

¹⁹ Ofcom is the licensing authority for civil use but CAA issue the licence on Ofcom's behalf.

which would inhibit the future application of AIP should only proceed where there has been a clear and fully justified decision that AIP is not suitable; ground-based and airborne use is considered separately and in most cases there will be more scope for achieving efficiency improvements by pricing ground stations than there is for onboard users.

Maritime

7.1 Introduction

As set out in the Audit's consultation document, the main issues relating to spectrum efficiency in the maritime sphere are radar and communications usage and pricing. This chapter sets out the Audit's conclusions on where pricing should be applied, following further discussions with Ofcom and the Maritime and Coastguard Agency (MCA). It also covers the potential for increased sharing in the maritime bands; and suggests a review of VHF requirements.

Generally, the same arguments apply to maritime coastal stations as to aeronautical ground stations, which are covered in Chapter 6, where there are fixed stations whose use of spectrum deny use of that spectrum by others.

7.2 On-board licences

Ofcom are proposing to issue lifetime licences for ship radio on-board equipment. This implies relinquishing the tool of pricing for *on-board* systems. Following discussions with Ofcom and the MCA on the different maritime licence classes the Audit agrees that free, lifetime licences for ships radio, rather than administered incentive pricing, is appropriate, for the following reasons:

- All on-board frequencies are internationally mandated except for Coastal Station Radio (CSR) and two Coastal Station Marina frequencies which are considered separately below. This means that the radio equipment is manufactured to internationally recognised standards, which are mandatory for all SOLAS (International Convention for the Safety of Life at Sea) vessels. Any change in spectrum use or related technology application would need to be agreed internationally. The UK does not therefore have scope for unilaterally introducing changes in spectrum use (the UK attempting to act alone would be impracticable; could lead to compatibility violations, and could generate or cause UK users to be subject to harmful interference). In these cases the opportunity cost of use is zero.
- Non-SOLAS vessels still need to conform to the RTTED (Radio Equipment and Telecommunications Terminal Equipment Directive) and UK Radio Interface requirements, which, due to the need for international compatibility and benefits on common radio systems with SOLAS vessels, again cannot be amended on a purely national level.
- As vessels will be mobile, any interference is likely to be minimal and transient. Spectrum is not generally congested and all vessels requesting and legally entitled to obtain a licence will be granted a licence.
- Use of on-board systems will be mobile, in general communicating with a Coastal Station. The Audit feels that where pricing is justified, incentives could most effectively be applied at the Coastal station level – see below. It appears to be more effective to target incentives at the operators who have control over the technology choice, rather than targeting a multiplicity of individual users. This also avoids any 'double charging'.
- On-board licences also cover the use of commercial equipment through the use of a Notice of Variation. However, the spectrum cost of these services, and therefore the incentive to make more efficient use of spectrum, are

applied - where pricing is deemed appropriate - to the network operator rather than to the individual user (e.g. as is done with mobile phones, where the network operators pay the spectrum fee rather than each mobile user). As above this makes sense in terms of aiming incentives at the appropriate level.

- Spectrum frequency initiatives in many maritime areas may be best pursued through international bodies to achieve globally amended frequency allocations or equipment standard changes, rather than applying pricing on a national level.

The argument that the use of spectrum for on-board systems can be covered by applying incentives at the level of the Coastal Station does not apply to on-board radar. Under Ofcom's current proposals²⁰ these would not be subjected to incentive pricing either. The Audit agrees that this is also a sensible approach as:

- These on-board radars have to be internationally type-approved for SOLAS vessels, which, as above, means that there is little scope for the UK acting unilaterally;
- Pricing could in theory be applied to on-board radars on non-SOLAS vessels, as the same international restrictions do not apply. However, any beneficial effect this would have on spectrum use would be minimal due to the continued use of frequencies and equipment by SOLAS vessels;
- In addition, the UK must keep clear frequencies for use by visiting vessels. Therefore, as with radio equipment as covered above, the most appropriate route for encouraging spectrum efficiency would be through global changes rather than the UK acting alone.
- It is unlikely that applying pricing to a multiplicity of UK-registered individual users would have an effect in improving spectrum efficiency. Vessels may seek to register elsewhere in order to avoid the spectrum charge.

7.3 Coastal stations

As outlined above, the Coastal Station appears to be a more effective point at which to apply incentives – in this case pricing.

Coastal station radio (UK) licence (VHF). The spectrum for this use is not internationally harmonised, and the frequencies are for use purely within the vicinity of the UK and cannot be used in the waters of other administrations. There appears to be a good case for applying incentive pricing here. For example, the use of reduced bandwidths (from the current 25 kHz) would free up spectrum for use by Business Radio users, suggesting that a Business Radio AIP rate may be appropriate. There are some 15 simplex channels and 24 duplex channels. In the case of the latter, both the upper and lower frequencies may be used in simplex mode, potentially increasing the number of assignments. These channels are within sections of the band between 156 MHz to 163 MHz. There is considerable demand by BR users in VHF mid-band, in which these maritime bands are located.

Navigational aid licence (radar/radar beacons) for coastal stations:

Here the equipment is governed by the R&TTED, although compliance with the R&TTED is frequently demonstrated by the application of internationally recognised

²⁰ "Proposal to reform ship radio licensing" available at [http://www.ofcom.org.uk/consult/condocs/src/](http://www.ofcom.org.uk/consult/condocs/src/http://www.ofcom.org.uk/consult/condocs/src/)

standards. In the case of radar, use is fixed and there is no reliance on cooperation from the vessel. Incentive pricing here could be applied at rates similar to the mobile rates in adjacent bands in the lower bands and similar to the fixed rate of adjacent bands in the upper band. This could have a positive effective in encouraging the introduction of equipment which achieves target resolution with reduced use of spectrum. The relevant bands are 2.9 GHz to 3.1 GHz and 9.3 GHz to 9.5 GHz. It should be noted however that in-bound visiting vessels will continue to use existing technology specified by internationally mandated standards, potentially impeding benefits that might be achieved from freed up spectrum. In many ports (although not all), coast station radars operate “sector blanking” meaning that transmissions are inhibited when sweeping in the direction of land. There are some locations however where the angle of sector blanking possible may be minimal, in which case 360 degree operation is used. The Port of Aberdeen is an example of a radar installation where sector blanking is not employed. Not all radars are capable of operating sector blanking.

Differential Global Positioning System (DGPS) licence – VHF (UK) and MF (international). These licences are already charged at a higher rate than cost recovery (£250/£1000 annually respectively) to reflect the amount of spectrum being sterilised. The DGPS licence is used for improved accuracy in positioning systems. The systems are generally “closed” systems whereby only vessels belonging to a particular organisation (e.g. Port of London) are able to decode transmissions from that particular Coast station.

- DGPS VHF licence: Specific bands are allocated to this licence class, but as with CSR (UK), they are on UK frequencies only for use at UK Coastal sites. Reducing the bandwidth of the DGPS VHF assignments down to 12.5 kHz, 6.25 kHz or 5 kHz for example, would provide spectrum efficiency gains. Consequently there does seem to be a case for applying pricing here. If AIP was applied, then an appropriate rate might be the Business Radio rate. We understand that there is an uncertainty over demand for these services, and it therefore seems sensible for Ofcom to carry out further work into demand before making a decision on pricing.
- The DGPS MF licence uses frequencies from an international block but for operation in a “closed” system whereby only vessels belonging to a particular organisation are able to decode transmissions from that particular Coast station. Demand appears to have declined and alternative technologies may mean a lack of future demand for this service. Whilst there may be scope for incentive pricing here (potentially at either the equivalent MoD or Broadcast rate), we feel there is a need to carry out more work on future demand before deciding whether AIP is likely to be an effective tool.

A number of international MF and some VHF coast station frequencies being used by MCA for safety and search and rescue (including land) purposes.

These have historically not been charged for, although cost recovery charging is planned to begin in the next financial year. In principle, the Audit’s view is that applying AIP would be the correct approach here, possibly at a Business Radio rate to reflect the opportunity cost of use.

MCA would be liable for this charge, which should be calculated at the appropriate market rate. However, recognising the safety of life imperative for providing this surplus, once the AIP has been calculated and a charge applied, Government may then decide to subsidise this charge. For example, lifeboats are licensed, but this is

applied at a charity discounted rate. Charities which have safety of human life in emergencies as their objective are entitled to a 50 per cent discount in spectrum costs.

There are instances of where it does *not* seem appropriate to price coastal stations. These are:

- **Coast station radio (marina) licence (VHF).** Similar considerations apply here as to coast station radio (UK) licences. However, only two UK frequencies are involved and some uniformity is needed to resolve compatibility differences as vessels travel around the UK. Although there could in theory be some scope for applying pricing (for example to encourage use of one frequency at a time), in practice given the high usage of the limited number of frequencies all around the UK coast, coupled with no requirement for co-ordination, it is considered that there would not be a significant efficiency gain by applying pricing here.
- **Coastal station radio (international) licence (VHF).** The spectrum for such use is internationally harmonised and it is necessary to comply with the spectrum use of visiting vessels to ensure compatibility and safe navigation of the vessels. Unlike radar, spectrum used under the CSR (International) licence relies on compatibility/co-operation with the vessels. Hence unilateral amendment of frequency (bandwidth) is not possible. There therefore appears to be zero opportunity cost for this use and therefore no case for applying pricing.
- **Maritime radio supplier's licence/Coastal Station Radio Training Establishment Licence:** both of these licence classes have access to all frequencies covered by the ship radio licence, with attendant international restrictions as covered above meaning that pricing is impractical. The suppliers licence is used for demonstration, repair etc and the training school licences for training in competency for a maritime radio operator's certificate.

7.4 Conclusion on applying AIP

Where there are international requirements which mean that the UK has no scope to act unilaterally, the opportunity cost of use is zero and there is no merit in introducing AIP for these licence classes. In these cases, spectrum efficiency measures should instead be pursued through international negotiations to update frequency allocations or adopt new standards or through the prescription of carriage requirements for more efficient technology (but again these would need to be implemented for equipment satisfying internationally recognised standards).

However, where use is controlled or can be changed on a UK basis, and there is a technology choice for the use of equipment, there appears to be a good case for applying pricing as an incentive mechanism to ensure the effective use of spectrum. This appears to be the case with some coastal station licences as above. The development of pricing should be taken forward in parallel with aeronautical pricing, where these are linked (e.g. radar), especially where the two services share the same spectrum on a geographical basis (as in the 2.9-3.1 GHz band).

Recommendation 7.1: Ofcom, in conjunction with the MCA, should begin work to introduce Administered Incentive Pricing in the following licence classes: Navigational Aid (radar); Coastal Station (UK) radio; and Differential Global Positioning System (DGPS); including carrying out further work on future

demand as indicated in this chapter. This should be carried out to the same timing as the development of aeronautical pricing where there are linkages.

7.5 Pursuing changes through technical regulation

There may be cases where there is congestion around the UK and inefficient equipment is used but the UK has little or no unilateral power to act. In such cases, and as set out above, improvements to spectrum efficiency need to be addressed through pursuing regulatory and standards changes through international fora. The Audit urges the MCA to engage with such discussions, for example the work suggested in chapter 6 on unwanted emissions. Where it is possible to use the tool of carriage requirements to require the use of more efficient technology within the constraints of international requirements, the MCA should do so.

7.6 Sharing

There is already sharing inland with maritime radars in the 2.9 GHz to 3.1 GHz band. A report carried out for Ofcom into aeronautical and maritime efficiency²¹ recommended that the MCA should introduce sharing, in particular with PMSE, in the 3 GHz and 9 GHz maritime bands. The MCA see difficulties associated with this proposal, but have agreed that this should be examined in more detail in conjunction with the other users of the bands. This may be sharing with PMSE, or with other services such as Short Range Devices, video links, or requirements for disaster relief. The new sharing group would be an appropriate forum for this to be discussed at.

Recommendation 7.2: The MCA should examine in detail the possibility of increasing sharing in the 3 GHz and 9 GHz maritime radar bands, and should report on this issue to the Sharing Group for discussion with other users of these bands.

7.7 VHF

The report mentioned above also recommended that “an in depth study of all UK applications within the bands 156.0 MHz to 158.5 MHz and 160.6 MHz to 163.1 MHz (including Appendix 18 (to the Radio Regulations) international maritime channels as well as Coast Station Radio private UK maritime channels) should be considered”.

This would include an assessment of: the future VHF spectrum requirements of the UK maritime industry with a view to rationalisation of the current spectrum; current and future maritime public correspondence needs; and take account of the need to: ensure 25 kHz fitted ships would be able to operate as intended for an agreed period; ensure 161.975 MHz and 162.025 MHz are maintained for AIS; and seek to achieve a reduction in the number of two-frequency channels for port operations and ship movement.

Due to congestion in the bands (we understand for example that Ofcom has had difficulty in assigning channels in the South and South East), the Audit feels that in the case of the CSR international bands, whilst taking into account international use,

²¹ *Assessment of the technical, regulatory and socio-economic constraints and feasibility of the implementation of more spectrally efficient radiocommunications techniques and technology within the aeronautical and maritime communities* available at <http://www.ofcom.org.uk/research/technology/other/sss/ay4620/?a=87101>

there is merit, for the longer term, in such a study being carried out jointly by the MCA and Ofcom.

Recommendation 7.3: Ofcom and the MCA should carry out a review of international applications in the bands 156.0 MHz to 158.5 MHz and 160.6 MHz to 163.1 MHz to ascertain the feasibility of promoting simplex use of the duplex channels and/or the conversion to 12.5 kHz bandwidths.

7.8 Future needs

The MCA have made us aware of future spectrum need they may have for HF email. However, this is a commercial requirement rather than safety-of-life and as such should not in the view of the Audit receive any preferential treatment for allocation or assignment.

Emergency and Public Safety Services

8.1 Introduction

This chapter covers issues relating to Emergency and Public Safety Services.²² It is recommended that the role of the Public Safety Spectrum Policy Group is augmented, to provide an overarching policy focus for Emergency Services spectrum issues, and possibly to act as a band manager for Emergency Service spectrum.

8.2 Policy coordination

As set out in the Audit's consultation document, the current spectrum management responsibility for the emergency and public safety services is divided between Ofcom - as the technical spectrum manager - and the Public Safety Spectrum Policy Group (PSSPG) dealing with more strategic and policy issues. This reorganisation was prompted by the Review of Radio Spectrum Management in 2002, with the rationale that the disparate spectrum holdings of the individual emergency services could be managed more effectively if done collectively.

The PSSPG's role has tended to focus on single issues requiring resolution, to good effect, but to the exclusion of more long term or strategic policy issues and decisions. It is clearly difficult to coordinate policy when the different services are overseen by different Government departments and with many different decision makers within each force below this. However, the Audit's view is that there is a need for an overarching view to be taken of the emergency services and their spectrum needs, (as envisaged by the first Cave Review). The Audit is therefore of the view that the role of PSSPG should be recast to reflect the following roles – which will entail significant changes in the operation of the group:

1. Acting as a single point of contact for 'the emergency services';
2. Taking into account the competing needs of each service and other potential users;
3. Future procurement projects – considerations of (i) spectrum requirements; (ii) the potential benefits of a joint procurement and (iii) interoperability between services:
 - (i) As with the Ministry of Defence (mentioned in Chapter 5) the spectrum requirements flowing from new procurement decisions need to be factored into the process at a much earlier stage, and these should be discussed in a coordinated way in a forum with all services represented;
 - (ii) There will of course be different requirements for each user, such as quality of service, geographical area etc, and procurement timings may not align. However, there are likely to be both cost savings and interoperability advantages from the different services liaising on future procurement requirements. A full assessment should be made, as part of

²² We use the PSSPG definitions: 'Emergency Services' as those organisations listed in SI 1989 no 1976 as being permitted to use a blue warning beacon on their vehicles; 'Public Safety Services' as identified by an emergency service as an organisation with which that emergency service would wish to communicate by radio in the context of an emergency incident or emergency response or an organisation which has a statutory duty or commercial obligation to provide maintain or repair those elements of the national infrastructure on which the immediate safety, health or welfare of the nation depends.

procurement business cases, of the economic benefits of joint systems/procurement (including the benefits of joint infrastructure as well as the operational radio systems themselves)

- (iii) Interoperability between systems – ensuring that where appropriate the communications networks of the different services can talk to each other

4. Assessing likely future needs for the emergency and public services (which would then feed into the UKSSC Forward Look (see Chapter 2)) and discussing how these needs might be addressed.

5. Encompassing all of the above, the Audit is of the view that a band manager is needed for Emergency Service spectrum, to actively manage existing holdings, coordinate use and address new requirements. This band manager role could be performed by a significantly enhanced PSSPG, or this function could be contracted out. In discussions with the sponsor departments for the Emergency Services, they too have expressed the view that this is necessary.

For PSSPG to be able to fulfil these roles, some changes would be needed (which will require revisions to PSSPG's terms of reference):

- (a) Senior policy officials, rather than technical experts, as currently, should attend PSSPG (particularly from the sponsor departments for the Emergency Services). There is a technical group which supports PSSPG – the remit of this group should be clearly defined so that the main PSSPG grouping can discuss policy rather than technical issues
- (b) The reporting/decision making route for PSSPG should be formalised.
- PSSPG currently reports to the NFPG, a sub-group of UKSSC. However, NFPG normally agrees business by correspondence, meaning that few routine and policy focused PSSPG issues reach the point of discussion at UKSSC. The Audit's view is that there would be merit in PSSPG reporting directly to UKSSC to facilitate more routine reporting on and discussion of Emergency Services spectrum issues in the high level forum of UKSSC. This might however require a rethink of the Chairmanship arrangements – for example PSSPG currently has an independent chair, which might cause problems in terms of attendance at a Cabinet Committee
 - To secure high level agreement to major issues e.g. procurement decisions, there should also be clear reporting and decision making lines to Ministers. The Audit suggests that the reporting lines are examined.
- (c) The structure feeding into PSSPG needs to be better coordinated, e.g. to articulate the future requirements of all separate services. The Audit is of the view that it should be a matter for the parents departments to decide how best to improve coordination, but that this should be taken forward through PSSPG. We understand that this issue has been raised before and encountered a resource problem. In the Audit's view, this is an issue which should be given priority as effective management of Emergency Service spectrum in future relies on there being a well known pattern of future requirements and plans for addressing these. PSSPG sponsor departments should either be resourced to carry out this work themselves or contract it out.
- (d) PSSPG should either take on the role of band manager, or contract this out. If the former, the technical side of band management would be passed to the technical committee and resources would need to be strengthened.

Recommendation 8.1: the role and composition of PSSPG should be reviewed.

- *The Audit recommends that PSSPG focus on policy rather than technical issues, and attendance at the group amended accordingly;*
- *PSSPG should consider whether it, or a contracted party, should act as a band manager for public sector spectrum. If the former, PSSPG will need more staff resource.*
- *Section 8.2 sets out some roles that PSSPG should fill*
- *PSSPG reporting lines should be changed so that PSSPG reports directly into UKSSC. Ministerial reporting should be examined.*
- *In addition, future needs of all the services need to be properly assessed, and coordinated through PSSPG. If PSSPG sponsor departments cannot do this they should fund contracted work.*

8.3 Access to emergency service spectrum- the sharer's list

Airwave O2 limited ("Airwave") currently provide communications networks to Emergency and Public Safety Services (having been awarded this contract through a competitive process) in the 380-385 MHz paired with 390-395 MHz band. These bands were allocated to Airwave by administrative assignment (with Airwave holding the licence) – the justification for this being that the spectrum was needed to provide a safety critical service. Possible expansion spectrum is discussed below. Eligibility for access to the Airwave network is governed by the Sharer's List. Organisations apply to Ofcom to be placed on the Sharer's list, and once they are accepted onto it they may proceed to agree contractual arrangements with Airwave.

Currently, to apply to join the sharer's list requires that the following criteria be met:²³

- Respond to emergencies;
- Proportionality
- Civilian; and
- Interaction with those who respond to emergencies (only if the main purpose of being on the Airwave service is interaction with the Emergency Services and if the proposed user requires instant connection with the Emergency Services).

This process does not seem a particularly efficient means of policing access to spectrum. For example, although the Sharer's list is now of substantial length, we understand that many of these organisations have not gone on to pursue access to the Airwave network. This means that there is a potentially large claim on the Airwave network's resources should these organisations choose to seek to agree contracts. This, and the issue of the Sharer's list overall as a means of policing access to Emergency and Public Safety Services spectrum, is something that PSSPG may wish to consider in the context of ensuring that sufficient spectrum is available to meet Emergency Service needs. It would also be relevant to Ofcom's considerations if a request for further spectrum were to be made in the future.

8.4 Expansion spectrum

Ofcom's SFR:IP Interim Statement set out that Ofcom had decided to identify 2x2 MHz in the 410-425 MHz band to meet the expanded requirements of the emergency services. Ofcom issued a consultation document in October 2005 elaborating on these proposals.²⁴ It set out Ofcom's decision that, in the light of an independent

²³ Additional criteria with regard to compliance with CESG requirements for access to security algorithms has implications on which individuals can use the service. The aspect is outside Ofcom/PSSPG

²⁴ http://www.ofcom.org.uk/consult/condocs/spectrum_award/

technical assessment, a pair of 2 MHz bands should be made available (at 410-412 MHz/ 420-422 MHz), but noted that the final amount required may be less than this, depending on the outcome of the emergency services' ongoing procurement decisions.²⁵

Ofcom's intention is to administratively assign this spectrum to the emergency services, and to charge AIP. The AIP rate will be set initially at a rate comparable to that for existing PAMR (Public Access Mobile Radio) use and then reviewed following the auction of the remaining spectrum, which should produce market information about the value of spectrum in this band. The Audit agrees with this approach. Discussions are underway as to who will hold the licence for this spectrum – it is possible that the licence could be held by one of the sponsor departments for the Emergency Services, or by a third party, such as a band manager for Emergency Service spectrum, as mentioned above.

Ofcom's consultation document explained that: "Ofcom expects that over time the needs of most or all users of spectrum for access to spectrum resource can be met from the market. However, Ofcom accepts that while market mechanisms are still developing there may be circumstances under which it is appropriate to provide spectrum directly to the emergency services." It continues: "The decision to assign the spectrum to the emergency services was made in the light of a specific set of circumstances prevailing at the time and should not be taken as setting a precedent for assigning spectrum for emergency services administratively rather than through a competitive process."

The Audit considers that this approach is in line with the proposals in Chapter 2 for access to spectrum for public sector use going forward. The same should apply to emergency and public safety services seeking to secure spectrum in the future as to other public sector users – needs should be met through the market unless there is an exceptional case, where the process and criteria set out in Chapter 2 would need to be applied and satisfied to justify any new spectrum through administrative assignment.

8.5 Civil contingencies

It is recognised that there will be times of emergency when contingency arrangements will need to be put into place which enable emergency, safety and security services to operate outside their normal spectrum allocations. The Cabinet Office is responsible for coordinating and agreeing a timely and smooth move to emergency operating arrangements. The Audit has not considered the impact on spectrum usage in such circumstances but recognises that it could be significant.

The Audit is of the view that this process for dealing with emergency situations needs (i) to be able to be responsive to a range of possible emergency scenarios; (ii) should work through some of these scenarios to see what the spectrum implications would be and (iii) that the final process needs to be flexible enough to allow swift discussion and agreement of the emergency arrangements to be put into place, recognising that the nature of a potential emergency is unlikely to allow much time for these discussions to take place.

²⁵ Subsequently ODPM have announced that they intend to award the firelink contract to O2 Airwave. See <http://www.odpm.gov.uk/index.asp?id=1002882&PressNoticeID=1994>

Science Services

9.1 Introduction

This chapter focuses on radioastronomy and Meteorological Aids. Ofcom's plans for introducing RSA for radioastronomy are commented on in more detail; in particular the costs to be imposed, the effect of the pricing formula on the choice of site location and the tradability of RSA. Met Office use of spectrum is also covered, and a recommendation made to give the Met Office control over the budget for its spectrum fees.

9.2 Recognised Spectrum Access

As set out in the Audit's consultation document, Ofcom intends to introduce RSA for radioastronomy. Ofcom consulted on this proposal in April 2005 and issued a statement in October²⁶.

The timescale is for RSA to be brought into operation in 2006. This could be done by issuing a single RSA to the Particle Physics and Astronomy Research Council (PPARC) covering all six radioastronomy sites and frequency bands. In the two-thirds of radioastronomy bands which are shared with active services, Ofcom intend to apply pricing to RSA for radioastronomy on an opportunity cost basis, based on Administered Incentive Pricing (AIP). Exclusively passive bands will be zero rated due to there being zero opportunity cost of use because the international regulatory framework precludes alternative use (cost recovery charges may still be applied here). The Audit supports this move as a way of better recognising the use by radio astronomy of spectrum, and applying incentives to this use.

The Particle Physics and Astronomy Research Council (PPARC) currently pay a spectrum fee to Ofcom, calculated on a cost recovery basis, of £345k a year. With the introduction of RSA, and applying AIP to this, the costs are likely to rise. Ofcom will be consulting on the detailed formulation of AIP-based fees for radioastronomy RSA. The Audit understands that the proposed fee algorithm is likely to take account of bandwidth, coordination area and an impact factor. An impact factor, which is a measure of the constraints on deployment of transmitting equipment as a result of avoiding interference to radioastronomy sites, would be calculated by assessing the frequency with which alternative services are denied assignments in this band.

There are thirty bands to which RSA is likely to be applied, and the fees are likely to be concentrated in around three frequency bands due to number of sites, bandwidths and size of coordination zones and the estimation of potential alternative use.

9.3 Trading

The Ofcom statement on radioastronomy says that "It is desirable in principle for radio astronomy RSA to be tradable to give increased incentive for spectrum efficiency. However, the incentive effect will depend on whether or not the radio astronomy community is allowed to retain the proceeds of trading. Ofcom does not intend to introduce trading for radio astronomy RSA at this time but will revisit this issue in the light of the Government's response to the Cave Audit."

²⁶ <http://www.ofcom.org.uk/consult/condocs/astronomy/statement/>

As outlined elsewhere in this document, the Audit is of the view that market mechanisms and the accompanying incentives should be applied to public bodies wherever possible. In this context, the Audit is of the view that it would be desirable to make radioastronomy RSA tradable. There were two main objections raised to this during the consultation. Firstly, it was suggested that radioastronomers do not have scope to alter their spectrum use. Although the Audit appreciates that there are fixed frequencies for radioastronomy, which does limit choice, it agrees with Ofcom that there are choices which can be made, for example in the location of sites or the protection afforded to them, which can affect the spectrum use and potentially free up spectrum to be traded for other uses. The second objection was that this would not incentivise better use of spectrum because PPARC were not permitted to trade and therefore could not gain from revenues generated.

The Audit team has discussed this issue with the Office of Science and Technology (OST), who fund the Research Councils. The OST have undertaken to consider allowing PPARC to benefit financially from spectrum trading (perhaps through a profit sharing arrangement, or an agreement whereby OST gain from any reduction in AIP fees but PPARC can retain income generated over and above this). If this issue can be satisfactorily resolved, the Audit recommends that radioastronomy RSA should be made tradable.

Recommendation 9.1: Subject to resolution of incentives issues as set out in Chapter 9, radioastronomy RSA should be made tradable.

9.4 Meeting spectrum costs

Currently, PPARC do not include spectrum costs in individual grants for facilities, instead paying the total spectrum fees directly to Ofcom. PPARC plan to continue this when RSA is introduced. The Audit view is that, with the introduction of RSA meaning that separate agreements are in place and agreed for each facility, PPARC should either decide to take a more active role in managing the spectrum requirements of each facility or cascade the costs to individual facilities who have responsibility for day to day management so that they have the responsibility for the best use of spectrum and stand to either gain from any reduction in usage or pay the costs of increasing it. This decision is likely to be affected by discussions on retention of any income generated.

Recommendation 9.2: PPARC should review the structure for devolving spectrum charges, and consider (in the light of discussions on income retention) either cascading charges to users or taking a more active role in spectrum management, to enable pricing to be applied at the level of those able to make decisions about the use of spectrum by these services.

The Office of Science & Technology has undertaken to meet the increased costs of radioastronomy use of spectrum through the introduction of RSA until 2007/08. This coincides with the timing of the next Spending Review and it will be for the OST and PPARC to discuss at that stage how to meet the costs of spectrum fees.

9.5 Location of sites

The Audit's consultation document flagged up the issue of the location of radioastronomy sites, given that their protection requirements are often extensive in geographical terms, with protection zones often covering urban areas where the

spectrum demand is likely to be higher and therefore the restrictive impact of the protection needed is greater.

When deciding where to locate a site, the following are some of the factors taken into account: degree of manmade emissions; telescopes requiring certain angles and separations; and the need for a quiet environment. Many of the current six radioastronomy sites are located for historical reasons, and were sited at a time when their locations and protection zones may have been more 'radio-quiet' than today. It is accepted that the cost of relocating these sites is likely to be prohibitive and may not be justified by subsequent spectrum efficiency gains. However, in the future, where a decision is made over locating a site, the Audit is of the view that spectrum availability should be taken into account. RSA if applied at opportunity cost level through AIP should enable this to happen. For example, through the impact factor, it is likely to be the case that the RSA cost is lower in a non-urban area, and this might affect the decision making process. If a decision was made to locate in a spectrum-congested area this would be done with knowledge of the costs of spectrum as an input. PPARC has a rolling programme of reviewing science priorities and sites, and costs will clearly be a factor in this.

PPARC's view is that it is likely that the next generation of radio telescopes (to be built in 2015-2020) will be located overseas, due to the radio environment and cost. Due to advances in technology there are more possibilities to access data from abroad and use remote monitoring. It is therefore likely that there will be a reduction in radioastronomy activity in the UK in the future (although there will remain a requirement for differential global measurements to be made).

9.6 Future needs

Future needs for radioastronomy, among other issues such as sharing, are discussed at the annual meetings of the Radioastronomy space sciences frequency committee. The Committee includes representatives from the MoD and Met Office. The agenda of the World Radio Conference 2007 (WRC-07) includes a number of science services issues. These include protection of radioastronomy and Earth Exploration Satellites from unwanted emissions and an additional allocation to Met Sat and active EESS.

9.7 Met Office use of spectrum

The Met Office use 400-406MHz for radiosonde measurements, dropsondes, DCP (Data Collection Platform) uplinks and telemetry from tethered balloons at Cardington.

Radiosonde usage is concentrated in the middle of the band to avoid interference at the margins. The sondes are carried below meteorological balloons and are not recovered after use so need to be low cost products. Remote sensing by satellite is increasingly being used instead. Satellites can cover a larger area and provide better horizontal measurement, but sondes are likely to continue to be needed in parallel at least for the foreseeable future, given the advantage in vertical resolution in measurement by this equipment. It has not yet been determined what the usage of radiosonde systems will be in the long term, but no significant change in use is expected in the UK within five years. Universities and the military also use sondes, and usage needs to be coordinated with them.

The UK is at the forefront of technology developments in this area. The Met Office has been one of the main customers to cause international manufacturers to reduce

the spectrum occupation required by standard radiosondes. This has led to an ETSI standard being introduced in Europe for digital radiosondes.

In older radiosondes, a spectrum occupancy of greater than 200 kHz was required. With advances in electronics, transmissions are more stable, and the use of GPS navigation to track the radiosondes enables the bandwidth necessary for operation to be reduced to below 100 kHz. The Met Office will be carrying out testing to establish whether spectrum can be released with the use of the new radiosondes. The Met Office intend for a new operational radiosonde frequency plan to be produced by mid-2006.

Internationally, reduction of spectrum use for radiosondes is limited by the relatively poor performance of existing systems in other countries. 400.15-406 MHz is an international primary allocation for Met Aids therefore the notified operations of other countries must also be respected. Met Office radiosondes travel over other countries from time to time during the year. This band therefore has to be coordinated internationally, as well as with the primary satellite services operated for meteorology in this band. Decisions are made on what equipment is used, and spectrum requirements factored into this, driven purely by the international market – devices are developed to operate in the internationally agreed frequencies.

9.8 400-401 MHz

The Met Office use of 400-401MHz is ending, as they no longer need to operate on this frequency. The Met Office estimates that they could stop using this sub-band from mid 2006.

9.9 RSA for Met Aids

In some cases, Met Office use of spectrum may be a suitable candidate for Recognised Spectrum Access as a means of gaining recognition of usage in future (see Chapter 2 for further discussion of the application of RSA to Crown bodies). The Audit would encourage the Met Office to consider bands where the application of RSA may be helpful to recognise spectrum usage.

9.10 Charging

The MoD currently pays the AIP for spectrum in use by the Met Office. For example, the charge for 401-406 MHz is £1.2 million per annum. MoD and the Met Office are currently in the process of drawing up a Memorandum of Understanding governing their spectrum management relationship. The Met Office carries out operations for the MoD using its bands, but these are covered by a separate contract (with associated costs of providing the service included). The Audit is of the view that there would be benefit in the Met Office being responsible for their own spectrum costs, as this would place the incentive to make better use of spectrum with the organisation which has responsibility for making decisions about equipment and technology and associated spectrum needs.

The Audit considers that the best way of addressing this would be for the spectrum budget for the bands used by the Met Office to be transferred to Met Office responsibility. As part of this process the MoD and Met Office will want to consider the current and future use of these bands. To avoid gifting windfall gains to the Met Office the MoD may for example wish to transfer only part of the budget if it feels that not all of the bands are needed.

Recommendation 9.3: The budget for spectrum charges for the bands used by the Met Office should be transferred from the MoD to the Met Office to be managed there. MoD and the Met Office may wish to review the use of these bands before this transfer takes place.

9.11 Future needs

The Met Office currently liaises with Ofcom and neighbouring countries if they have new needs. The ITU agenda includes papers on this band, information on sondes getting data and a recommendation on the interfering power of sondes which will lead to the updating of technical requirements. The world metrological organisation (WMO) feeds into working party 7C which in turn feeds into WRCs.

Fixed links

10.1 Introduction

Use of spectrum by fixed links was included in the Audit's terms of reference as an area where (in common with the public sector) a significant amount of spectrum is allocated, many of the allocations are historic, and where the market may not deliver the optimal use of spectrum under the current and planned spectrum management regime and without intervention by the regulator. In fixed links this is largely due to the link-by-link nature of licensing which imposes constraints on the possibilities for trading and liberalisation. The Audit concludes that it is too early to tell whether a different spectrum management approach for fixed links bands is likely to be necessary – the market has yet to be tested – but that these options should be kept in mind.

The Audit has not concluded that funded clearance projects should be taken forward immediately in the bands it has examined. In the 1.4 GHz and 1.5 GHz bands the Audit recommends that this option is reconsidered following revealed market value through an auction in an adjacent band. With 1790-1798 MHz, the option of an auction is preferred, with additional suggestions of charging to reflect current use of the band and potentially migrating users out in the longer term. The Audit considers that Ofcom should consider applying Recognised Spectrum Access to receive-only earth stations in 3.6-4.4 GHz and 11 GHz – both of these bands present a significant spectrum management challenge. Given the current uncertainty over how market mechanisms will operate in fixed links bands, the Audit is also of the view that the planned auction in 32 GHz should be given a high priority in terms of testing the market, if it is shown that there is sufficient interest in this band.

As suggested in the Audit's consultation document, it is also recommended that Ofcom should establish a one-off 'Spend on technology to Save on spectrum scheme' of around £500k and with criteria as suggested in this chapter.

10.2 Trading and Management

BT and Cable and Wireless previously had use of and management responsibility for some of the fixed links bands, but over a period of some ten years, ending in 2004, these were brought back into Ofcom management to ensure that maximum use was being made of the bands and to aid competition. All fixed links bands are now actively managed by Ofcom. Looking solely at fixed links this was an appropriate approach to promote competition. However the management and usage structure which now exists raises questions about the scope for tradability and in particular liberalisation in these bands. To trade, it would certainly be possible to buy up a single link, but in isolation this would restrict the purchaser to making exactly the same use of that link as the previous user. To change use from fixed links to another service, or even to change the nature of the links, would require multiple purchases to acquire the entire spectrum-area necessary.

It is the Audit's view that it remains to be seen how this will be addressed through the market – although there could conceivably be a problem, it is too early in the introduction of spectrum markets to make a firm judgement at this stage. If it does appear that there are barriers to market mechanisms delivering efficient spectrum

management in fixed links bands there may be a case for regulatory intervention to address these barriers. The Audit's consultation document asked for views on possible regulatory approaches to managing fixed links bands – few respondents commented. Aside from allowing the market to manage, clearance projects, overlay and band managers are all options, and are covered below.

10.3 Band managers

One possibility is that 'band managers' will emerge who will purchase spectrum and manage fixed links assignments within that spectrum for individual users (much as Ofcom does now but for commercial gain). Ofcom have recently set out how such an approach would work under the current spectrum management regime²⁷.

The Audit's consultation document asked whether there were any barriers to such a management approach being applied. None of the respondents identified any barriers. Until a fixed links band comes to market it is too early to predict whether such an organisation will emerge (without regulatory intervention). The Audit concludes from this firstly that it is too early to decide that there is a need for regulatory intervention in the market to establish such a management approach, and secondly that it is important to see what happens in an auction of a fixed links band to inform such decisions in the future. The auction of 32 GHz could provide a valuable opportunity to assess the success of a market based approach to delivering new spectrum management methods – see below for more discussion of this band.

10.4 Spectrum Efficiency Scheme re-farming

The Audit has examined a number of fixed links bands (see below for details). In several cases the Audit was considering whether there was a case for clearance of a band to deliver it to a higher value use. Such action can be funded from the Spectrum Efficiency Scheme (SES), managed by Ofcom, if:

- the benefits outweigh the costs;
- the grant will promote efficient management and use of the spectrum;
- Ofcom can re-order, or 're-farm' spectrum in a timely manner without impacting on existing Licensee's rights and expectations.

Compensation can be paid as an acknowledgement that re-farming has a cost associated with the enforced redundancy of equipment. Any financial implications over and above current SES budgets would be a matter for Ofcom and HMT to discuss.

10.5 Overlay auction

An alternative mechanism for reorganising use in a spectrum band is an overlay auction. This may be desirable where a band has become fragmented and its use sub-optimal, or as a timely way to replace incumbent use with alternative higher value users. Some key features of overlay licenses, likely in future to be awarded by auction, are:

²⁷ Award of available spectrum: 412-414 MHz paired with 422-424 MHz, Annex 8, 13th October 2005, http://www.ofcom.org.uk/consult/condocs/spectrum_award/spectrum.pdf

- the overlay licensee is granted rights to a block of spectrum which may include both encumbered and unencumbered spectrum;
- the overlay licensee is permitted to start using any available unencumbered spectrum immediately;
- the regulator may serve revocation notices on incumbents, so that eventually the whole band will be unencumbered; and
- the overlay licensee is able to negotiate with incumbents the take over of their rights before the end of any revocation notice period. This will be facilitated by trading of incumbents' rights. An overlay licensee might also take on the role of band manager, serving both incumbents and new users.

It would be necessary before any such auction to provide bidders with full information on the winner's rights to the spectrum and the rights of incumbents, and on the possibility of the winner negotiating with incumbent licensees for access to their spectrum. An overlay auction may be an appropriate option for the 1790-1798 MHz, 1.4 GHz and 1.5 GHz bands.

10.6 Pricing

Fixed links are licensed on a point to point basis (the defined spectrum volume between the two connected points) rather than giving national or regional rights to a given band of spectrum. The fee structure is now based on the opportunity cost of using spectrum and the amount used. The charge for each link is based on an algorithm that reflects characteristics including the bandwidth used and the path length to arrive at an estimate of the opportunity cost. This algorithm has recently been revisited increasing the average charge by around 15% to better reflect the value of spectrum used. Prices have increased by a significantly larger amount in the 4 GHz and lower and upper 6 GHz bands than at higher frequencies, reflecting greater spectrum scarcity. However, even after these increases, total revenues from the lower fixed links bands remain tens of times lower in total (defined as national revenues per-MHz) than AIP rates applied to mobile services below 3 GHz. This difference is driven in part by the greater demands from alternative services below 3 GHz, and the way the services are licensed is not directly comparable, but Chapter 3 on pricing covers the issue of the fixed-mobile rate differential in more detail and recommends that it should be addressed.

Chapter 3 also sets out some of the specific issues and options for pricing shared spectrum. For aeronautical pricing the Audit is advocating the imposition of a national per-MHz price which would then be divided up between users by a coordinating body. The purpose of this approach is to enable pricing to be consistent across different services and to incentivise the users, working in collaboration with their regulator, to use the spectrum more intensively and occupy a smaller total bandwidth. The proposed aeronautical pricing system differs from the current link-by-link approach for pricing commercial fixed links, another type of spatially-shared spectrum use where coordination problems could impair the ability of market mechanisms to deliver optimal spectrum use across different services. An equivalent approach for fixed links to the aeronautical model would be a band manager. As noted in Section 10.3 Ofcom have recently set out how a band management approach could work under the current spectrum management regime.

10.7 Band specific

1.4 GHz and 1.5 GHz

The equipment operating in this band is different and less sophisticated than that in 4 GHz and above. The links in this band can operate at very long distances but also have smaller bandwidths and payloads than those in higher bands. Ofcom and its predecessor the Radiocommunications Agency have in the past cleared some fixed links out from below 3 GHz, often in response to international decisions allocating the spectrum to a particular technology. This reallocation has been motivated by the growth in alternative high value applications using frequencies in this part of the spectrum. This calls into question whether fixed links are the economically optimal use for frequencies at 1.4-1.5 GHz, and, if they are not, whether the market will be able to deliver a higher value use, due to reasons discussed above.

The recent revisions to fixed links prices have on the whole increased the charges in lower bands more than higher bands. However the total level of pricing imposed on the 1.4 GHz and 1.5 GHz bands has not increased due to the narrow bandwidth occupied. The pricing systems are different but the aggregate level of fees remains far below charges on adjacent mobile spectrum, at an average of a few thousand pounds per MHz for the UK compared to a £240,000 per MHz standard national mobile rate. This disparity in pricing should be addressed as part of the work recommended in Chapter 3 on Pricing.

Due to the existing use, this band may be suitable for an overlay auction. If the market cannot deliver a change of use, and that is thought desirable, there may be a case for a funded spectrum clearance project, if the criteria set out at the beginning of this chapter are met. Part of this consideration would be the costs versus the benefits of clearing one service in favour of another. There is an opportunity to assess the market view of the value of this band through the planned auction of the adjacent 1452-1492 MHz in 2006-07.

A clearance project for the 1452-1492 MHz band (involving Ofcom serving 15 years notice to clear out existing fixed links use in the band, including links used by the ambulance service) was triggered by the international reallocation of the band to digital sound broadcasting. Ofcom now plan to auction this band. It is unlikely to be economically desirable to use similar notice periods for clearance in future, especially if it leads to valuable spectrum being underutilised for a significant part of the notice period and severely delays transfer to a potentially higher value use.

Once a comparative value has been ascertained from auctioning the adjacent band, and experience of the market operating at this frequency has been gained, Ofcom should review the 1.4 GHz and 1.5 GHz bands in the light of this, and give further consideration to the merits of a clearance project if appropriate.

Recommendation 10.1: Ofcom should review the 1.4 GHz and 1.5 GHz bands in the light of the market value and environment revealed by the upcoming auction of adjacent L-Band spectrum. Ofcom should then give further consideration to the merits of a clearance project or overlay auction as appropriate.

1790-1798 MHz

The Audit's consultation document set out that the Audit would consider the case for early clearance of the current Emergency Service use of this band. The Emergency Service use is due to vacate this band completely in 2009-10 as these services migrate to alternative commercial systems which have their own fixed infrastructure.

To make a case for Spectrum Efficiency Scheme funding to migrate this use out of the band earlier - considering the case against the criteria set out at the beginning of this chapter - it appears unlikely that the cost of moving the existing service would be outweighed by the benefits accruing to a new user.

This is in part because the value of this band to a new user will be subject to additional constraints imposed by the MOD's existing use. The MoD use (space operations) is such that it is difficult, for security reasons, to define the usage. Ofcom has listed this band as subject to an award in 2007-08, recognising the existing Emergency Service as a constraint on this band at present and the MoD use remaining a constraint. Discussions are underway on the extent to which the MoD operations would impose constraints on commercial use and how it might be possible to define these uses for the purposes of an auction. For example, in the recent DECT guard band consultation document²⁸ restrictions on the band due to MoD use were set out in terms of the radiated power spectral density from specific sites to enable a potential commercial user to judge the impact.

Depending on the outcome of the discussions between Ofcom and MoD, an award could be made based on the acceptance of constraints imposed by MoD and Emergency Service use, or made based on the acceptance of constraints imposed by MoD, with it falling to the commercial operator to either work around Emergency Service use until it vacates or to negotiate with the Emergency Services for them to migrate out of the band at an earlier date (for example through an overlay auction).

The Audit is keen that Ofcom pursue the resolution of the issues currently affecting the possibility of a successful auction, aiming for an award as they currently plan, in 2007-8. In designing the award Ofcom will need to take account of existing use, and an overlay auction may be an effective tool for managing this.

The Emergency Services pay by link for their use of this band. The MoD do not currently pay a fee for their use of this band, however it is clear that their usage does have a cost in terms of the effect on other potential users. **The Audit is therefore of the view that the MoD should pay Administered Incentive Pricing for this band.** The level of charge will depend on the level of constraint MoD imposes on the band. For example, if it has been possible to define usage parameters in a way which enables other users into the band, then the charge would reflect the extent of use afforded to others.

The above options assume that MoD use is permanent. There may however be an option of migrating the MoD use out of this band into an internationally harmonised space operations band, probably over a longer timescale of 10-15 years. Although a longer term aim, **the Audit is of the view that this possibility should be pursued, and considered in the context of potential alternative use for this band – where there is a potential higher value use there may be a case for migrating the MoD out of this band.**

There is a parallel process ongoing to make an award of this band, extended to cover 1785-1805 MHz in Northern Ireland.²⁹ There is no Emergency Service or MoD use and subsequent constraint in NI.

²⁸ <http://www.ofcom.org.uk/consult/condocs/1781/>

²⁹ <http://www.ofcom.org.uk/consult/condocs/sfrip/statement/#content>

This band is also identified for potential use by digital radio microphones and wireless audio devices. Any potential award for this band will therefore need to be designed in a technology neutral way which makes it possible for operators of these services to participate and secure spectrum for their use as they see fit. There has to date been little interest in the use of this band for these purposes.

Recommendation 10.2: With regard to 1790-1798 MHz:

- (i) Ofcom should pursue the resolution of the issues currently affecting the possibility of a successful auction, aiming for an award as they currently plan, in 2007/8;**
- (ii) The MoD should pay Administered Incentive Pricing for this band;**
- (iii) The option of migrating the MoD use out of this band into an internationally harmonised space operations band, probably over a longer timescale of 10-15 years, should be considered as an option for this band**

3.6-4.2GHz

There is currently a mixture of services – fixed terrestrial links, fixed satellite earth stations and fixed wireless access - using this band, and the 3.6–3.8 GHz part of the band is also likely to be harmonised throughout Europe for new Broadband Wireless Access technologies.

3.6-3.8 GHz was made available to Fixed Wireless Access services in the mid-1990s. Users are expected to coordinate their operations and this can lead to problems finding operational locations under the conditions which were attached to entry into the band. Ofcom is currently reviewing the use of the technical coordination process.

One of the problems with this coordination process is that as receive only earth stations are not licensed, their location is not known and it is therefore impossible to plan or coordinate around them. The Radiocommunications Agency previously trialed a system of voluntary registration for earth stations but with little take-up. Ofcom's SFR:IP statement said that Ofcom would look to clarify and regularise use in this band. This has been taken forward to date by an examination of more formal options, including the possibility of applying Recognised Spectrum Access to the receive-only services in this band. **Recognised Spectrum Access does seem an attractive solution for this band.** It would make current satellite use more transparent, give Satellite operators a degree of statutory recognition, and assist planning. Ofcom are also able to attach costs to an RSA, reflecting the economic cost of the spectrum use being recognised. If pricing were applied to RSA in this band, it would be a way of ensuring that spectrum costs were realised. RSA could also be made tradable. However RSA would entail further complications in planning with fixed services including FWA. An alternative would be for receive only earth stations to continue to operate on an un-licensed basis and be afforded no protection from other, licensed, uses of the band.

Another possibility is to look at more dynamic arrangement between satellite and FWA operators, for example sharing arrangements on a real-time basis between different services. There may be a role for Ofcom in facilitating this process but ultimately it would be for the companies themselves to discuss and agree such an approach. High transaction costs could be a drawback of a more dynamic approach. Alternatively, the band could be segmented.

There are six 90MHz channels in this band. The lowest channel and its pair were made available for Fixed Wireless Access and some migration of point to point fixed links undertaken to avoid any interference problems. However, the band is also shared with earth stations in the fixed satellite service. The 3.6 – 3.8 GHz band is also a candidate for new wireless applications and currently the ECC, through a Joint Project Team, is looking at harmonisation measures for Broadband Wireless Access in the 3.4 - 3.8 GHz band. This work is likely to result in pan-European harmonisation measures. Any new and extended use here would have to plan around the existing fixed links, including BWA, unless mechanisms are put in place to clear the incumbent fixed links from the band.

There does not appear to be a clear case here for an SES funded clearance of a particular service. Given the early stage of development of the market for other potential services and the nature of the legacy use it is not clear that the costs would outweigh the benefits for regulatory intervention at this time. This does not of course preclude the possibility of a commercial interest using the market to make a different use of this band. Trading in this band would be one way of ascertaining the highest value use.

However, it is not presently clear what the best solution is for this band in terms of effective spectrum management. With a number of differing services operating in the band this poses a complex spectrum management challenge. Any solution is likely to need many and high level interactions between services. As a first step this would seem to be an ideal candidate band for RSA to be applied to receive-only earth stations, and the Audit considers that Ofcom should give this possibility detailed consideration. Following this, there may be technical solutions worth considering.

Recommendation 10.3: Ofcom should consider the use of RSA for receive-only satellite earth stations in the 3.6-4.2 GHz band, along other options for improving the management of this band.

11 GHz

This band is shared between fixed terrestrial links and fixed satellite service downlinks – currently conveying domestic satellite television delivery. The band has been closed to new fixed links applications for some time to avoid interference to the domestic reception of the broadcasting satellite services. Fixed links, if admitted to this band, would pay AIP as applied to other fixed links, calculated by the fixed link algorithm. The satellite downlinks do not pay a fee specifically for their use of the 11 GHz band. Where the uplinks are based in the UK these pay a fee (currently being revised to reflect the recent changes in the fixed link fee, as a potential alternative use of the band) in their uplink bands. Where the uplinks are outside the UK, no fees are paid for UK spectrum use.

It has been previously suggested that the introduction of RSA could be a way of helping to achieve more optimal use of bands shared by terrestrial and satellite services by giving satellite downlinks comparable incentives to use spectrum in the most efficient manner as those to which licensed services are subject. The Audit is aware that this may raise a wider number of policy issues in the particular case of the 11 GHz band. Nonetheless, the pressures on fixed links bands and expected future shortage of suitable spectrum below 15 GHz for essential telecommunications infrastructure, as discussed elsewhere in this report, highlight the existence of a real spectrum management problem that needs to be addressed in order to ensure optimal use of the band.

Such spectrum management issues are, in general, better solved by application of market mechanisms, as discussed elsewhere in this report. The introduction of RSA in this band would enable market mechanisms to be applied here. However, given the wider policy issues, the possibility of introducing RSA in this band and how this would be done will need further careful consideration before firm conclusions can be reached about how best to manage the band. **The Audit recommends that Ofcom gives priority to gathering information to enable it to decide whether, when and on what terms the introduction of RSA would be beneficial.**

Recommendation 10.4: The Audit recommends that Ofcom gives priority to gathering information to enable it to decide whether, when and on what terms the introduction of RSA in the 11 GHz band would be beneficial.

32 GHz

Ofcom is carrying out a market study on this band (along with 10 GHz, 28 GHz and 40 GHz) to determine the spectrum packaging and award design for the two thirds of the 32 GHz band currently unused (the remaining one-third is currently allocated for fixed links). Ofcom expects to launch an awards process in 2006-07.

The Audit's main interest in this band is as a candidate for a band manager approach as a way of addressing the potential restrictions that the nature of fixed links licensing imposes on the ability of the market to deliver spectrum to the highest value use. The Audit's consultation document therefore asked for views from any prospective band managers on the attractiveness or barriers of such an approach in this band. We had little response on this question and no specific barriers were cited. One respondent said that they were unaware before reading the document that two thirds of the band was being made available, and could be used for a band manager approach amongst others.

Ofcom has sought to encourage innovative suggestions for managing the 32 GHz band, e.g. through a band manager of fixed links. Although there has been little interest to date in pursuing alternative approaches the market study being carried out in advance of this auction will provide useful information such as potential demand for this band and for which services, and will inform the award design.

If the 32 GHz award framework enables the option of band management it will be a good test case to ascertain the appetite and interest for new market models for managing fixed links spectrum (recognising that this band is in a very different part of the spectrum from the other bands being examined here, which may have very different levels of demand). The market study should provide more information on likely demand for this band, and, **if there should prove to be significant demand, the Audit considers it important that this award should be given a high priority in the interests of encouraging efficient spectrum management and obtaining information about the likely effect of the market in Fixed Links bands.** The award structure will of course need to be designed to allow for a number of different possible management approaches.

Recommendation 10.5: If the market study being carried out reveals significant demand, Ofcom should give the 32GHz award a high priority in the interests of encouraging efficient spectrum management and obtaining information about the likely effect of the market in Fixed Links.

10.8 Spectrum Efficiency Scheme ‘Spend to Save’

The Audit’s consultation document asked for views on the Spectrum Efficiency Scheme (SES), and in particular whether there would be benefit in Ofcom running a one off ‘Spend on Technology to save on Spectrum’ bidding round to highlight the role of the SES in giving grants to promote the efficient use of management of the spectrum and to encourage attractive proposals to be brought forward. There was support for this idea in the consultation responses, and the Audit therefore recommends that this option is taken forward by Ofcom. A one-off bidding round of £500k is suggested. Criteria for such a scheme should be decided by Ofcom, but might include:

- Demonstration of reason why market mechanisms and commercial interests cannot deliver the proposed funding;
- That spectrum efficiencies will be realised by the action proposed, either by releasing spectrum or admitting additional sharers;
- If the action proposed will result in spectrum being released to be traded by the incumbent, there could be an undertaking to repay the SES grant following a successful sale which realised more than the value of the grant

Recommendation 10.6: Ofcom should run a one-off ‘Spend on Technology to Save on Spectrum scheme’ of around £500k. Criteria are suggested in Chapter 10.

Annex A

Terms of Reference

1. To identify the major spectrum holdings for consideration.³⁰
2. To audit the use of and the operational need for major spectrum holdings, having regard to the potential future demand, with a view to identifying spectrum that could possibly be opened for other use.
3. To recommend a strategic approach for making such spectrum available, taking into account operational, financial, technical and international factors, and to indicate possible timescales. This could include proposals for spectrum clearance projects.
4. To review the effectiveness of ongoing incentives for public sector users to maximise efficient use of the spectrum and whether this could be enhanced, including through the treatment of shared bands and the means of meeting new spectrum requirements of public sector spectrum users.

³⁰ Investigations will concentrate on, but are not limited to, frequencies below 15GHz

Annex B

Audit of Major Bands

Explanation of traffic light markings:

Share/release

A marking in this column indicates the potential for spectrum to be released or for additional sharers to be admitted (There may be other users of these bands, such as the Maritime and Coastguard Agency, who would need to be involved in discussions about alternative uses of bands before final decisions were made).

Other action

This column indicates the possibility for other action to be carried out in this band. This may include pursuing changes at an international level, reviewing the services currently in a band, or the potential application of pricing to a band.

Red - the Audit considers that there is no scope for either release of spectrum from this band, the introduction of other services on a shared basis into this band, or other action. This judgement applies to the current situation and also looks five years ahead.

Amber - The Audit's opinion is that there could be scope for action in this band, either for release of spectrum or admitting users into the band on a shared basis, or in other areas, but that there are obstacles to such a change being effected. The Audit has taken the view that it is possible for these obstacles (detailed in the 'Action' column) to be overcome, or for significant steps to have been taken towards addressing them, in the next five years. This marking also indicates where the Audit has not been able to obtain sufficient information from the user of a band about current use (and future use, where such information is available) to make a judgement and is therefore recommending that further technical work is carried out.

Green - the Audit is of the view that there is scope for action in this band, either to release spectrum or admit other users on a shared basis, or to take other action. The Audit's opinion is that such change could be effected either immediately or within the next few years.

Band coverage

The bands covered by this Audit were set out in the Audit's consultation document. In some cases a band has been widened to give a better picture of current and future potential use. Where the band examined differs from that set out in the consultation an explanation of this is given in the text.

Basis of marking

The Audit has made a judgement on a traffic light marking for the bands listed based on the information provided to it by those currently using the band. It is recognised that in some cases future uses for band by the incumbent may not as yet have been identified and quantified (the main body of this report sets out a process for addressing this information gap going forwards), and that when this is done any spare capacity identified will first be used to meet these needs.

Band and use	Usage	Share/ release	Other action	Action
<p>137-154 MHz (bands within) METEOROLOGICAL SATELLITE MOBILE</p>	<p>137-138 MHz 137-138 MHz 142.5 -143 MHz 149-149.9 MHz 153.5-154 MHz</p>			<p>Share/release and other action: The MoD should look at the possibility of consolidating and condensing their mobile use in these four bands, which could then free up spectrum for sharing or release</p>
<p>MOBILE SATELLITE Space Operation (space to Earth) Space Research (space to Earth).</p>	<p>137-138 MHz 149-149.9 MHz 137-138 MHz 137-138 MHz 142.5 -143 MHz</p>			
<p>Meteorological Aids.</p>	<p>153.5-154 MHz</p>			

Band and use	Usage	Share/ release	Other action	Action
<p>230-400 MHz FIXED</p> <p>MOBILE</p> <p>AERONAUTICAL RADIONAVIGATION</p> <p>Radiolocation Radio Astronomy</p> <p>Mobile Satellite</p> <p>NATO band type 1, "Essential for mobile satellite. Air/Ground/Air and specific maritime and terrestrial communications". ARFA manage this band in Europe.</p>	<p>230-328.6 MHz. 335.4-399.9 MHz</p> <p>230-328.6 MHz. 335.4-399.9 MHz 328.6-335.4 MHz.</p> <p>230-328.6 MHz 232-236 MHz 326.5-328.5 MHz</p> <p>235-322 MHz 335.4-339.9 MHz</p> <p>225-400 MHz</p>			<p>Share/release:</p> <p>It is accepted that major changes in this band are unlikely in the short-to-medium term due to the nature of international planning and usage.</p> <p>However, the scope to admit other users into this band has been demonstrated. The MoD should consider the possibility of extending this at the margins of this band (e.g. further inroads in the 380-400MHz sub band).</p> <p>Other action:</p> <p>See the chapter of this report on Pricing for a recommendation that Administered Incentive Pricing be applied to this band.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>400.15-406.1 MHz METEOROLOGICAL SATELLITE (E->s)</p> <p>METEOROLOGICAL SATELLITE secondary (E->s)</p> <p>METEOROLOGICAL AIDS SPACE OPERATIONS</p> <p>Space Operations (secondary)</p> <p>SRS</p> <p>MSS</p> <p>FIXED</p> <p>MOBILE except aeronautical</p> <p>Mobile Satellite (E->s)</p> <p>NATO band</p> <p>“Requirement for Met-Aids.”</p> <p>Band under MoD management.</p> <p>Overall responsibility for the band may change between MoD/DSM and the Meteorological Office as an Agency of MoD.</p>	<p>400.15-401 MHz</p> <p>401-403 MHz</p> <p>400.15-406 MHz</p> <p>401-406.0 MHz</p> <p>400.15-401 MHz</p> <p>400.15-401 MHz</p> <p>400.15-401.0 MHz</p> <p>401-406.0 MHz</p> <p>401-406.0 MHz</p> <p>406.0-406.1 MHz</p> <p>400.15-406 MHz</p>			<p>Share/release:</p> <p>New equipment has the potential to make more efficient use of spectrum. This should create opportunities for rationalising the use of this band and potentially releasing some for alternative use</p> <p>Other action:</p> <p>See the Science services chapter for a recommendation on handling spectrum fees between MoD and Met Office, with associated review to consolidate / replan use into the minimum required spectrum with improved designs now available.</p>

Band and use	Usage	Share/ release	Other action	Action
	<p>Information informs UK weather forecasting, maritime forecasts and condition reporting, military operations and of course air transport.</p> <p>There is also Licence Exempt use of Short Range Devices in this band.</p> <p>406.0-406.1 MHz - Low power satellite emergency position indicating radiobeacons as covered under footnotes 5.266 & 5.267 of the ITU Radio Regulations.</p>			
<p>406.1-410 MHz. FIXED MOBILE RADIO ASTRONOMY Radiolocation.</p>	<p>Used for general mobile communications, including USAF bases in East Anglia, some of which have been moved down from 430-450 MHz.</p> <p>Use of the band is constrained by the need to protect co-primary Radio Astronomy which is used at all six major observatories in the UK.</p>			<p>Share/release and other action:</p> <p>The military use of this band appears light compared to the density of activity which might be expected in a comparable civil use band.</p> <p>There would therefore seem to be scope for admitting increased alternative use into this band (e.g. PMR)</p>

Band and use	Usage	Share/ release	Other action	Action
<p>410-430 MHz FIXED. MOBILE. RADIOLOCATION. Space Research.</p> <p>NATO band, "Requirement for land and naval radars and airborne radars over ocean areas".</p>	<p>This band is used for military land management radios and mobile networks. Most of these are for security, crash and fire networks and logistics support. The band is also used for flight termination systems and remote firing switches on missiles at MoD test ranges.</p> <p>Use of 420-430 MHz is overshadowed by the need to protect the long-range early-warning radar system at Fylingdales. The radar is established under an inter-governmental agreement and is expected to remain for the foreseeable future.</p> <p>Programme Making operates in this band on a geographically restricted basis.</p> <p>The MoD have already released much of this band on a channel by channel basis. The released spectrum has been used for civil PAMR and its future use is under discussion.</p> <p>Spectrum within these bands has been identified in the SFR:IP for civil use and Ofcom has issued a consultation document on the award of spectrum at 412-414 MHz paired with 422-424 MHz. Consultation closes on 24 November 2005. The Emergency Services use 410-412MHz and 420-422MHz and the MoD 1x1MHz of this.</p> <p>Two frequencies within this band (416.4 & 416.675 MHz) are used to provide a datalink for flight calibration of radionavigation aids.</p>			<p>Share/release and other action:</p> <p>There appears to be good potential for further release of spectrum in this band below 420 MHz.</p> <p>The MoD systems below 420 MHz are mobile and therefore more easily moved than the major military radar use in the 420-450MHz band covered next.</p> <p>There could be demand for this band for PMR services displaced from Band III and UHF-2.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>430-450 MHz FIXED MOBILE RADIOLOCATION Amateur Amateur- Satellite</p> <p>NATO band, "Requirement for land and naval radars and airborne radars over ocean areas".</p> <p><i>This band was not included in consultation document. It has been included here to more fully reflect MoD's use in this area (as linked to previous band covered).</i></p>	<p>Use of this band is overshadowed by the need to protect the long-range early-warning radar system at Fylingdales. The radar is established under an inter-governmental agreement and is expected to remain for the foreseeable future.</p> <p>Numerous Channels are used for base management radios and land mobile networks. Most units operate equipment in this band for security, crash and fire networks, maintenance teams, logistic support etc. The number of these has been increasing as existing military assignments are phased out of bands in 400-430 MHz in order to permit increased civil use. However, protecting the early-warning radar imposes constraints on the planning of these assignments.</p> <p>There is extensive use of this spectrum for civil PMR (mostly in the major conurbations) though this is also now constrained by the need to protect Fylingdales. A coordination tool has been developed to manage the future assignment process (both civil and military) in this band. The band is also used for Programme Making on a geographically restricted basis.</p> <p>The Amateur service operates across 430-440 MHz including the Amateur Satellite service in 435-438 MHz. This is on a secondary basis in the UK but primary across the rest of Region 1.</p> <p>Many Short Range Devices operate in a European harmonised band at 433 MHz.</p>			<p>Share/release:</p> <p>Fylingdales creates severe constraints in this band. However, the Audit is of the view that there may be scope for optimising civil use. This might be done through reconfiguration of existing (other MoD non-radar) use, assisted by the planning tool used in this band.</p> <p>It is noted that there is ongoing interference and usage monitoring in this band.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>590-598 MHz</p> <p>AERONAUTICAL RADIONAVIGATION Land Mobile</p> <p>DAP manages radionavigation. Ofcom manages mobile.</p>	<p>Known as Channel 36 (due to its position in the TV Broadcasting spectrum) this now contains low and diminishing radar uses (not operated by the MoD) and the future of this is under consideration as part of the UK's planning for RRC06.</p> <p>Band also contains licensed radiomicrophones used in locations away from the radar.</p>			<p>Share/release and other action:</p> <p>Ofcom, with assistance from the CAA, should take forward discussions with the incumbents of the 590-598MHz band with a view to vacating the band (including the option of a funded clearance project). These discussions should take place in the context of the wider debate on broadcasting spectrum taking place in RRC06 in order to properly assess the costs and benefits of such action</p>

Band and use	Usage	Share/ release	Other action	Action
<p>870-960 MHz</p> <p>MOBILE</p> <p>NATO band, "Essential for between 10-60 MHz for TRR, of which 10 MHz should be harmonised for cross-border training" – Fixed and non-aeronautical Mobile.</p>	<p>The MoD manages 2x6 MHz of this spectrum of which 2x4 MHz is already shared with the GSM-R railway signalling system which is being rolled out across the UK's railways by Network Rail.</p> <p>Civil TETRA-based systems may operate in the bands 872-876 MHz and 917-921 MHz. Private TETRA systems may also operate in 871-872 MHz and 916-917 MHz on a non-protected basis in accordance with the agreement between MoD and Ofcom</p> <p>880-915MHz and 925-960MHz are used for GSM</p> <p>The MoD uses this spectrum for Tactical Radio Relay – either its wide-band Triffid equipment or Ptarmigan. The channels for this equipment are allotted to and assigned on a daily basis by the appropriate Army District Headquarters. While primarily used in the conventional army training sites, there is a need to train personnel in the use of these links UK wide and in particular in urban areas so that links can be deployed them in the event of a civil emergency.</p>			<p>Share/release and other action:</p> <p>Given the use of this band for training and operational purposes, and in view of the sharing arrangements that have already been agreed, the MoD should consider the scope for admitting additional sharers into the remaining (albeit relatively small) part of the band.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>960-1215 MHz AERONAUTICAL RADIONAVIGATION- SATELLITE (space-to- Earth) (space-to-space)</p> <p>NATO band "Requirement for TACAN, IFF & JTIDS/MIDS". CAA and MoD use. Joint management</p>	<p>UK operates 42 ground-based Civil Secondary Surveillance Radar systems. Their use of the two paired channels at 1030MHz & 1090MHz is critical for safe aircraft operation. Military IFF shares with civil use.</p> <p>UK operates 125 Distance Measuring Equipment beacons (using 960-1215MHz with 1 MHz channels), 49 of which are paired with VOR, and 60 of which are paired with ILS (or MLS). Beacon frequencies are notified internationally. There are 32 fixed MoD sites throughout the UK, plus extensive use for maritime and air-air TACAN.</p> <p>JTIDS (military Joint Tactical Information Distribution System) operates (frequency hopping) in 969-1206 MHz, but avoids both SSR/IFF channels by 20 MHz, and provides tactical data communication between military aircraft, and between military aircraft and the ground. JTIDS is also used by NATO partners.</p> <p>Galileo E5 signal (1188-1208 MHz, 20 MHz).</p> <p>GPS L5 signal (1164-1188 MHz, 24 MHz) – safety-of-life use including aviation – though UK may not use this signal.</p>			<p>Share/release: Unlikely to be scope for unilateral action (for UK to release spectrum or change use) due to international constraints, the mixed nature of use and safety obligations.</p> <p>Other action: The Audit is of the view that there could be scope for rationalising navigation-aid systems (e.g. DME, VOR, NDB), though it expected that DME/TACAN would be retained. However removal of other systems might additionally allow DME/TACAN to be re-planned to use a smaller amount of spectrum while continuing to satisfy the navigation requirement.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>1215-1350 MHz RADIOLOCATION AERONAUTICAL RADIIONAVIGATION RADIIONAVIGATION RADIIONAVIGATION- SATELLITE (space to Earth) (space to space) RADIIONAVIGATION- SATELLITE (Earth to space) EARTH EXPLORATION- SATELLITE (active) SPACE RESEARCH (active) Amateur Amateur-satellite (Earth to space)</p>	<p>1215-1350 MHz 1300-1350 MHz 1215-1350 MHz 1215-1300 MHz 1300-1350 MHz 1215-1300 MHz 1215-1300 MHz 1240-1325 MHz 1260-1270 MHz 1215-1350 MHz 1215-1350 MHz</p>	<p>Major long-range (250 nautical miles or more) aeronautical radar band with both civil (air traffic control (ATC)) and military (ATC and protection of airspace) applications. Civil stations are placed mainly above 1243 MHz, while military naval and air defence radars use the band 1215-1365 MHz</p> <p>UK operates 11 aeronautical radars (civil) in this band, each of which would use at least two operating frequencies. Most radars are now based on TWT, though three magnetrons remain, and the four latest radars use solid state transmitters with frequencies overlying the older magnetron based radars at these locations. 1212-1365 MHz offers seven, 20MHz channels. Frequency reuse is employed on only four civil frequency assignments in the UK, mainly due to long operating ranges.</p> <p>Windprofiler radars operate in the range 1270-1295 MHz. These are used for weather forecasting and aircraft safety around airfields. These typically operate near-vertically but might interfere with navigation radars through reflections from illuminated aircraft.</p> <p>MoD also uses the band to transfer radar information from the radar to the controller or user through effectively an application-specific fixed link and for local ad hoc security devices.</p>	<p>Share/release:</p> <p>Unlikely to be scope for unilateral action (for UK to release spectrum or change use) due to international constraints, the mixed nature of use and safety obligations.</p> <p>Other action:</p> <p>See the Aeronautical and Pricing chapters on pricing radar bands and improving coordination, both to encourage more effective use of the radar bands.</p>	

Band and use	Usage	Share/ release	Other action	Action
<p>1375-1400 MHz. 1427-1452 MHz. FIXED</p> <p>MOBILE (except aeronautical mobile)</p> <p>MOBILE</p> <p>SPACE OPERATION (Earth to space)</p>	<p>Satellites require protection (and are normally afforded international protection), especially when low towards the horizon, even if no UK uplink. Any UK RNSS uplinks are expected to be in C-band. It is believed that other countries may wish to deploy RNSS systems, and this would further constrain UK use of this important band. EESS use is for active spaceborne sensing and has international protection</p>			
<p>1375-1400 MHz 1427-1452 MHz 1375-1400 MHz 1427-1452 MHz 1427-1429 MHz</p>	<p>This paired spectrum is primarily used for radio relay equipment tactical training. These bands are also used for wide-band radio equipment providing security surveillance, video and data links control of aerial targets and essential aeronautical telemetry for military test and development.</p> <p>We understand that military use of the band is expected to increase as core fixed infrastructure for Army communications are displaced from 225-400 MHz.</p> <p>Proximity to the Radio Astronomy band at 1400-1427 MHz imposes some planning constraints on the use of the band.</p> <p>1427-1452 MHz is also used for telemetry for airborne platform development. (particularly carefully protected).</p> <p>MoD use has been consolidated here from several other bands.</p>			<p>Share/release:</p> <p>If there is pressure on adjacent fixed links bands this should be examined as a candidate band for additional terrestrial fixed links</p> <p>Other action:</p> <p>Pricing in this band may be currently too low due to the fixed-mobile differential (see the Pricing chapter for more detail)</p>

Band and use	Usage	Share/ release	Other action	Action
<p>1559-1626.5 MHz AERONAUTICAL RADIONAVIGATION RNSS (s->E) (s -> s) MSS (E -> s)</p> <p>MSS (s->E secondary)</p> <p>RADIOASTRONOMY</p> <p>MoD/DAP jointly manage RNSS and radionavigation, Ofcom manages the other services.</p> <p>UK 4 band.</p>	<p>1559-1626.5 MHz 1559-1610 MHz 1610-1626.5 MHz</p> <p>1613.8-1626.5 MHz 1610.6-1613.8 MHz</p> <p>The lower sub-band 1559-1610 MHz contains the main civil-use radionavigation satellite service channels for GPS, Galileo and GLONASS. These are used by aircraft for navigation purposes in addition to the wider civil commercial and recreational uses. Local ground-based transmissions to enhance the RNSS service, particularly for use as a landing aid (under aeronautical radionavigation allocation) have been considered, and now wider application to extend coverage underground or inside buildings has been proposed. RNSS signals are also widely used for accurate timing signals in addition to conventional navigation purposes. There are no other uses of the lower sub-band.</p> <p>The upper sub-band above 1610 MHz is shared between radioastronomy and commercial MSS services. No UK navigation use of the upper sub-band has been identified, though visiting equipment may require the Radionavigation allocation to be maintained.</p>			<p>Share/release and other action:</p> <p>The services in this band mean that it is in effect managed at a global level. It is therefore unclear that there is scope for unilateral action from the UK, and progress at an international level seems unlikely.</p> <p>However, the systems operating here probably do not need the whole band to operate in, and this should be borne in mind should the systems mix in this band change or the likelihood of seeking change on an international level change.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>2310-2450 MHz FIXED MOBILE Radiolocation Amateur Amateur-Satellite</p>	<p>Military use of this band includes fixed, telemetry and mobile services and long-range airborne telemetry links which are particularly carefully protected. Some of this use is by both the RAF and the USAF for training purposes. We understand that here is increasing demand for spectrum in this band for telemetry including possibly for Unmanned Aerial Vehicles (UAVs). Future generations of Radio Relay equipment is expected to be designed so that it can operate across this band. The MoD's BOWMAN Personal Role Radio also uses this band.</p> <p>There is a Europe-wide allocation to a variety of low power devices in the sub-band 2400-2483.5 MHz and there is military interest in the use of some of these technologies.</p> <p>The sub-band 2310-2380 MHz is also used by the Home Office / Scottish Executive by agreement with the MoD. However, this imposes some constraints on military use. The emergency service use is for video links some of which are moving up to spectrum at 3400-3600 MHz.</p> <p>Civil Programme Links operated by the JFMG operate in 2390-2450 MHz. These channels are of limited use due to the amount of interference experienced from other civil systems (including ISM) above 2400 MHz.</p> <p>The sub-band at 2400-2450 MHz is used for a variety of licence-exempt, civil low-power systems including video senders, radio local area networks (including Bluetooth), RF Identification (including railway systems) etc.</p>			<p>Share/release and other action: MoD information on detailed assignments in this band show that the MoD has a multiplicity of uses here and that the band is widely used. We understand that MoD has current and emerging requirements for aeronautical use in this band. However, the current use of the band is a result of an historical build up of assignments. There should therefore be scope for rationalisation of MoD use.</p> <p>In addition, WRC-07 is considering international spectrum needs for airborne telemetry and UAVs). This discussion will affect potential future uses for this band and therefore influence the review of use of this band.</p> <p>There may also be scope for the other uses in this band (e.g. fixed links) to be rationalised, which would also need to be taken forward by the MoD as the primary user of this band, New sharing technologies may provide new sharing opportunities in this band in the future.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>2700-3400 MHz RADIONAVIGATION AERONAUTICAL RADIONAVIGATION RADIOLOCATION Radiolocation EESS (active) SRS (active)</p> <p>MoD/DAP jointly manage the radionavigation service. MoD manages radiolocation. Ofcom may licence maritime radionavigation service in the 2900-3100 MHz band.</p> <p>NATO Band “Requirement for land, airborne and naval radars.” NATO Band “Essential for land, airborne and naval radars.”</p>	<p>This radar band has four main uses:</p> <p>a) Aeronautical Radionavigation – ground-based air movement radars which operate between 2700-3100 MHz. These have operational ranges between 60 to 150 nautical miles and provide the main radar coverage over UK territory and around airfields.</p> <p>b) Aeronautical radionavigation and radiolocation – ground based radars used for air defence and airspace protection, sometimes shared with air traffic management, operate between 2700-3410 MHz. Multiple frequencies may be used to provide elevation information, primarily for military purposes.</p> <p>(a and b) The UK has 40 fixed radars used for monitoring UK airspace and navigation routes. NATS are completing an upgrade programme to replace older, magnetron radars with more spectrally-efficient TWT or solid-state designs, though many airfields still operate magnetron-based radars (18 magnetrons, 4 solid-state, 16 TWT). NATS report congestion in parts of the UK making new assignments difficult to achieve. Some radar installations satisfy both civil and military aircraft navigation and airspace protection roles for a particular volume of airspace, while MoD also operate some defence-specific radars.</p>			<p>Share/release:</p> <p>The Audit is aware of several proposals for automated sharing within this band. These may have application elsewhere as well (although work to date has been specifically targeted on this band) but application will be more difficult the higher up in frequency and as systems become more mobile.</p> <p>There appear to be potential opportunities for both geographic release of spectrum, and for increased sharing as a result of technological developments on both commercial communications systems and radar systems.</p> <p>Audit recommendations should enable such increased use provided that safety and security requirements are not jeopardised, and international obligations remain satisfied.</p>

Band and use	Usage	Share/ release	Other action	Action
	<p>(c) Maritime radionavigation – primarily ship-borne, but also some land-based radars used for safety of maritime navigation – IMO carriage requirement for larger ships, operate in the band 2900-3100 MHz.</p> <p>The IMO mandates the use of S-Band radars on larger SOLAS vessels to provide longer-range (for maritime) sensing and better all-weather capabilities than are available purely at the other mandated frequencies at X-Band. Maritime radars are usually magnetron-based (size and cost) and may operate anywhere within the 2900-3100 MHz band. Any change to reduce the operating band would have to be agreed internationally and would not happen quickly. Racons (fixed navigation marker beacons) respond to radar signals in this band, and there are land-based navigation radars, some of which operate inland.</p> <p>d) Mobile military radars, high power, often combined ship-borne units with navigation, surface and airspace monitoring roles, but also associated with airborne radars such as AWACS, operating throughout the 2700-3410 MHz band, though normally minimising interference to other radars in the 2700-3100 MHz band.</p>			<p>It is however accepted that there is a need to take into account neighbouring countries operating Aero Radionavigation services in 2700-2900 MHz, and that military use of mobile radars presents a coordination challenge for enabling sharing.</p> <p>Other action:</p> <p>This is also a candidate band for radar pricing, which the Audit recommends is introduced.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>3400-3600 MHz RADIOLOCATION Amateur</p> <p>Band under MoD management. Ofcom and JFMG manage alternative civil, commercial and amateur uses.</p> <p>NATO Band “Essential for land, airborne and naval radars.”</p> <p>NATO Band “Requirement for land and naval radars.”</p>	<p>There have been civil services in this band for many years including programme making and a FWA system. Ofcom has agreed with MoD a licence for the FWA system in 2x20 MHz (3480-3500 & 3580-3600 MHz).</p> <p>MoD have formalised the FWA use by making the sub bands available for civil use for a 15 year period from 2002. MoD has indicated that it wishes to continue to manage the band in the expectation of future military use.</p> <p>The sub-bands at 3400-3440 and 3500-3600 MHz are widely used for Programme Making and new digital video technology is being introduced. The top channel at 3580-3600 MHz is being vacated to make way for FWA.</p> <p>There is continued military use of the lowest 10 MHz (below 3410 MHz) for station-keeping in association with AWACS airborne radars.</p> <p>The sub-band 3442-3475 MHz is used by the emergency services for “helly-telly” airborne video links.</p>			<p>Share/release:</p> <p>MoD has made 2x20MHz of this band available for leasing and will need to demonstrate a need for it to return to MoD at the end of this period</p> <p>One possibility would be for this to be auctioned, with MoD bidding if they do have future needs. We understand that the MoD do have projects planned for this band.</p> <p>Release/sharing should also be considered for the rest of the band.</p> <p>Other action:</p> <p>The pricing chapter also refers to the possibility of charging a proportion of AIP for a body to hold an ‘option’ on a band which is leased out through Ofcom. Such an arrangement would be an option for a band such as this in the future.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>4200-4400 MHz AERONAUTICAL RADIONAVIGATION</p> <p>Band jointly managed by MoD/DAP</p>	<p>The sole use is for radioaltimeters on aircraft, mainly in a ground-proximity warning role but also as part of the normal landing procedures. These are fitted to virtually every commercial aircraft. Most systems employ swept FM waveforms using the time delay between transmission and reception to derive distance. Use must be protected around all airfields and in general to provide backup for failure of other navigation systems.</p> <p>Alternative technologies could reduce the bandwidth required, and indeed many systems do not use the majority of the band now. Any changes would need to be pursued internationally to effect significant change in this band.</p>			<p>Share/release and other action:</p> <p>There is an ITU recommendation to examine narrowing this band but there has been no action taken to date. The UK should encourage and actively support such a move.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>4400-5000 MHz FIXED MOBILE FIXED SATELLITE (space to Earth) RADIO ASTRONOMY Radio Astronomy</p> <p>NATO Type 1 band "Essential for fixed, TRR and mobile systems".</p>	<p>4400-5000 MHz 4400-5000 MHz 4500-4800 MHz</p> <p>4990-5000 MHz 4800-4990 MHz</p> <p>4400-5000 MHz</p>			<p>Share/release and other action: From the information provided, the civil and military fixed links uses of this band look to be similar. There should therefore be scope for this band to be managed more commercially with civil and military use of fixed links managed together. It is noted that future military UAVs are targeted for this band. There is no set date for such equipment being brought into operation, however it could potentially use a significant portion of the band and will therefore affect MoD's consideration of future use</p>

Band and use	Usage	Share/ release	Other action	Action
<p>5000-5850 MHz AERONAUTICAL AERONAUTICAL RADIIONAVIGATION RADIIONAVIGATION MARITIME RADIIONAVIGATION RADIOLOCATION RNSS EESS (active) SRS SRS deep-space secondary FSS FSS MOBILE except aeronautical MOBILE except aeronautical Land mobile secondary (JFMG use) Amateur secondary Amateur Satellite secondary WAS/RLAN WAS/RLAN</p>	<p>5000-5250 MHz 5350-5460 MHz 5460-5470 MHz 5470-5650 MHz 5250-5850 MHz 5000-5030 MHz 5250-5570 MHz 5250-5570 MHz 5650-5725 MHz 5150-5250 MHz 5725-5850 MHz 5150-5350 MHz 5470-5725 MHz 5725-5850 MHz 5470-5850 MHz 5650-5850 MHz 5650-5850 MHz 5150-5350 MHz 5470-5725 MHz</p> <p>A complex band, with significant levels of civil/commercial use for RLANs (licence-exempt) and BFWA (4800 systems) which are internationally subject to technical and operational compatibility measures to protect radars. JFMG manages PM/SE use. Maritime and aeronautical navigation uses of these bands have in general significantly decreased with the exception of weather radars. Most larger aircraft use the band 5350-5470 MHz for forward-looking weather radar, primarily for detection of windshear. This is particularly important when the aircraft is on final approach and therefore most susceptible to interference originating from the ground. The aeronautical community has not yet expressed a clear preference for MLS over alternative automated landing systems such as ILS and GBAS, and therefore several bands are held available. MLS roll-out around the UK has been slow, and the initial allocation used for planning has been reduced to 5000-5150 MHz. A firm decision with international partners, either in favour or against MLS, would potentially release spectrum for alternative uses. MLS frequencies are by default paired with VOR/DME and ILS, leading to potential inefficiencies if this would cause MLS to spread across more spectrum than necessary.</p>			<p>Share/release: It is difficult to quantify the use in this band due to the diversity of systems in operation and the mixed management of the band. This suggests that the optimal planning of this band is not its current use and that there should be scope for rationalisation of the MoD and CAA use and management of this band, (acknowledging that other users in the band would need to be taken into account in doing so). In addition, bandsharing technology developments may be considered to help radars and WAS/RLAN/BWA coexist.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>MoD manages Radiolocation and above 5250 MHz.</p> <p>Within 5000-5850 MHz, Ofcom manages the Mobile, FSS, Amateur and Amateur Satellite services and authorises WAS/RLAN and BWA.</p> <p>JFMG share in 5470-5850 MHz.</p> <p>NATO “Essential for land, airborne and naval radars.”</p>	<p>NATO places importance on availability of the 5 GHz band for deployable point and area defence weapons systems, which might be used nationally around potential targets during times of conflict or to protect large international events or meetings.</p> <p>Maritime users prefer the greater frequency separation of pairing S and X-band radars.</p> <p>The RNSS allocation is used by Galileo for uplink EESS (active) use is for mapping, synthetic aperture radar and sea-level sensing.</p>			<p>Other action:</p> <p>Part of this exercise is the Audit’s recommendation that CAA seek to determine an overall aeronautical preference for MLS, ILS or GBAS and then work to close the non-preferred services with consequential spectrum release or re-use to satisfy other aeronautical requirements.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>7900-8400 MHz EARTH EXPLORATION- SATELLITE FIXED</p> <p>FIXED SATELLITE LAND MOBILE METEOROLOGICAL- SATELLITE</p> <p>MOBILE MOBILE SATELLITE</p> <p>NATO type 1 band "Essential requirement for satellite uplinks (mobile land and maritime)" and "Requirement for fixed in some countries."</p>	<p>The bands 7250-7750 MHz (down-link) and 7900-8400 MHz (up-link) are used for military fixed-satellite communications and are the primary link to UK forces operating overseas. This allocation is a harmonised NATO band and many partner countries have similar arrangements.</p> <p>The band is also used for military fixed links which the MoD co-ordinates to protect the satellite service from interference.</p>	<p>8025-8175 MHz</p> <p>7900-7975 MHz</p> <p>8025-8400 MHz</p> <p>7900-8400 MHz</p> <p>7900-7875 MHz</p> <p>8175-8215 MHz</p> <p>8025-8215 MHz</p> <p>7900-8400 MHz</p> <p>7900-8400 MHz</p>		<p>Share/release and other action:</p> <p>From the information provided it appears that the nature of UK use of this band is fixed and that there should therefore be scope for geographical sharing in this band.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>8500-10500 MHz (Excluding 9000-9500 MHz below)</p> <p>AERONAUTICAL RADIONAVIGATION EARTH EXPLORATION- SATELLITE MARITIME RADIONAVIGATION MOBILE RADIOLOCATION SPACE RESEARCH</p> <p>Amateur Amateur Satellite. Radiolocation</p> <p>NATO band "Requirement for land, airborne and naval radars" – type 2 in selected sub-bands. Band (excluding 9000-9500 MHz) under MoD management.</p>	<p>The wide 8500-10500 MHz band is used for a variety of military mobile radars, normally as part of larger weapons systems. A 500 MHz sub-band from 9000-9500 MHz is shared with civil radars including local coverage at airfields and the majority of maritime navigation radars. This sub-band is covered in greater detail below. MoD also operates a wide band aeronautical data system in this band.</p> <p>The sub-bands at 10.125-10.225 GHz and 10.475-10.575 GHz have been allocated to civil FWA. These were auctioned but the licences have since been recovered. These sub-bands have been included in the SFR:IP for potential future award.</p> <p>There are video links operated by the emergency services in the sub-bands 10.250-10.270 GHz and 10.360-10.460 GHz and for Programme Making by the JFMG in 10.30-10.36 GHz. These all respect geographical restrictions imposed by the MoD.</p>	<p>8750-8850 MHz</p> <p>8550-8650 MHz</p> <p>9500-9800 MHz</p> <p>8850-9000 MHz.</p> <p>10000-10500 MHz</p> <p>8500-9000 MHz.</p> <p>9500-10500 MHz</p> <p>8550-8650 MHz.</p> <p>9500-9800 MHz</p> <p>10000-10125 MHz</p> <p>10225-10500 MHz</p> <p>10450-10500 MHz</p> <p>9300-9500 MHz</p> <p>8500-10500 MHz</p>		<p>Share/release and other action:</p> <p>There is insufficient evidence to justify the need for 2GHz of spectrum for the radiolocation use currently in this band.</p> <p>There should therefore be scope for either releasing part of this band or opening it up to additional sharers.</p> <p>MoD indicates that they have potential future uses for this band such as wideband airborne radar and UAVs.</p>

Band and use	Usage	Share/ release	Other action	Action
<p>9000-9500 MHz RADIONAVIGATION AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION RADIOLLOCATION Radiolocation Radiolocation</p> <p>MoD/DAP jointly manage Aeronautical Radionavigation service. MoD manages the Radiolocation service. Ofcom manages the Maritime Radionavigation service, and additionally authorises low power detection systems.</p> <p>NATO band “Requirement for land, airborne and naval radars” – type 2 in selected sub-bands.</p>	<p>The X-band radar band has three main uses: a) Aeronautical Radionavigation – mainly surveillance of local movements around airfields, and ground-obstruction warning. Operating ranges are below 20 nautical miles, allowing good frequency re-use. b) Maritime radionavigation – primarily ship-borne, but also some land-based radars used for safety of maritime navigation – IMO carriage requirement in the band 9200-9500 MHz. 100 thousand radars estimated to be operational on ships, with several thousand onshore stations worldwide. The IMO mandates that vessels larger than 100 kT must have at least one X-band radar. Maritime radars are usually magnetron-based (size and cost) and may operate anywhere within the 9200-9500 MHz band, but a centre-frequency of 9410 MHz is typical. They normally use shorter pulses (hence larger bandwidth) and operate over shorter ranges than aeronautical radars, and are designed to operate close to and with interference from other, similar radars. Any change to reduce the operating band would have to be agreed internationally. Racons (fixed navigation marker beacons) and Search and Rescue Transponders (SARTs) respond to radar signals in this band. c) Mobile military radars providing surveillance and/or weapons guidance, potentially using high radiated power and multiple operating modes. The shorter wavelength makes X-band radars suitable for use on aircraft and military vehicles. Systems may operate across this band in association with wider radiolocation bands both above and below this band.</p>			<p>Share/release and other action: There appears to be extensive and well established use of this band. However, there is insufficient evidence to demonstrate that the total bandwidth is needed. Scope for releasing some of this band should therefore be explored. Possibilities for sharing should also be examined.</p>

Band and use	Usage	Share/ release	Other action	Action
	There is military use for battlefield surveillance and precision airfield approach radars, in addition to naval use for missile tracking. Precision approach may be used on a permanent basis in association with UK military airfields, and many military aircraft use radars operating in parts of this band. Other use should be associated with training and exercises.			
13.25-14.00 GHz. AERONAUTICAL RADIONAVIGATION RADIOLOCATION RADIONAVIGATION FIXED-SATELLITE (Earth to space). SPACE RESEARCH (active). Space Research Standard Frequency and Time Signal – Satellite (Earth to space). NATO harmonised band “Essential requirement for land, airborne and naval radars”.	Widely used for airborne Doppler radars, and naval radars. Assignments have been made to MoD establishments and ranges for the development and use of low-level air defence, surveillance and navigation radars.			Share/release and other action: Arrangements are in hand to formalise band sharing between military radiolocation and civil Fixed-Satellite services. MoD expects to use this band for future wideband radionavigation systems.

Band and use	Usage	Share/ release	Other action	Action
15.4-17.7 GHz AERONAUTICAL RADIONAVIGATION EARTH EXPLORATION- SATELLITE FIXED-SATELLITE FIXED MOBILE RADIOLOCATION Radiolocation Space Research MoD manages 15.7-17.3 GHz and radiolocation in 17.3-17.7 GHz. MoD/DAP jointly manage 15.4-15.7 GHz. Ofcom manages 17.3-17.7 GHz, wireless systems in 17.1-17.3 GHz and 15.43-15.63 GHz for the Fixed-Satellite service.	This band is used for a variety of wide-band data, command links, radars (including wideband airborne), survey, distance measuring and civil airfield movement control radars. The band 15.7-17.1 GHz has been harmonised for military use in NATO.	15.4-15.7 GHz 17.20-17.30 GHz 15.43-15.63 GHz 17.30-17.70 GHz 17.30-17.70 GHz 17.20-17.30 GHz 15.70-17.30 GHz 17.30-17.70 GHz 16.6-17.10 GHz	15.7- 17.3 GHz 15.7-17.1 GHz 17.3-17.7 GHz	Share/release and other action: There is insufficient evidence to justify the need for the whole of this band for the services operating within it. Opportunities for release/increased sharing should therefore be examined.

Annex C

Pricing of Individual Aeronautical Bands

This Annex sets out the band by band basis for the Audit's recommendations on pricing of individual bands set out in Chapter 6. It should be considered in conjunction with the details of band usage outlined in Annex B.

Ground-based radar

UHF Radar (590-598 MHz): See Chapter 6.

L-Band ATC Radar (1215-1375 MHz): Annex B notes the difficulties with reusing this spectrum for alternative services in the short to medium term and there is a need to coordinate with long-range radar uses in neighbouring countries. However parts of this band have previously been re-planned to enable the deployment of new GNSS and there are possibilities for reuse if further spectrum were to be released, and scope for compressing the current operation by the use of improved technologies if combined with effective planning.

We consider this band suitable for pricing, divided between civil and military use (Option C in Chapter 6). The main but not exclusive use is the NATS en-route system, which serves both civil and military aviation. Where there is limited civil use in 1350-1365 MHz it should be priced on an algorithm, Option B. It may be feasible to consolidate this use into the main 1215-1350 MHz band. Pricing should be discounted to recognise GNSS use, and if appropriate other uses such as radio amateurs.

There could be a possibility of a move away from primary L-Band radar for civil en-route air traffic control in the long-term. If this happened pricing would be an appropriate incentive to speed up the process. If MoD use and enduring security concerns about non-cooperating targets required continued primary operations in this band it could argue for greater charging falling on Government if this and not civil aviation requirements was the reason the band could not be reused.

S-Band Radar (2.7-3.1 GHz): There looks to be scope for re-using **2.7-2.9 GHz** for alternative services on a national basis, subject to coordination requirements. Pricing could be divided between fixed ground stations on a comparable basis (Option C) but there will also need to be consideration of whether military roaming uses, including naval, should bear any of the cost in reflection of interference caused.

In **2.9-3.1 GHz** there is also significant inland civil and military aeronautical use in this band, which is primarily allocated to maritime navigation use. As aeronautical use in the 2.9-3.1 GHz band is likely to be a substitute for using 2.7-2.9 GHz individual users should be charged on a comparable basis. The need to co-ordinate between maritime and aeronautical use in this band argues for the inclusion of MCA in the joint aeronautical spectrum planning body we are proposing.

X-Band Radar (9.0-9.5 GHz): This band has shared civil and military radar use, and there is global maritime radar use in the band 9.2-9.5 GHz. If military use prevents large-scale inland civil reuse of these frequencies then the national cost of the band should be imposed on civil aeronautical and military use (Option C), with the MoD picking up that element not covered by civil installation fees. At this frequency the main block on the scope for geographic reuse by other services is equipment mobility.

Ku-Band Radar (15.4-16.6 GHz): This band contains other military applications as well as both civil and military radar. As with X-Band the MoD should pick up part or all of the difference between this level of pricing and a full national per-MHz price if reuse is limited or prevented by MoD activities (Option C).

960-1215 MHz: SSR/DME/etc.

These services use a very large and valuable band. Therefore any possibilities for releasing part of the spectrum for alternative use or alleviating congestion within aeronautical uses should have a significant benefit. Annex B sets out further details on other uses.

SSR/IFF is an on-board internationally harmonised service essential to safety, uses a relatively modest amount of spectrum and does not appear to be suitable for pricing.

DME (Distance Measuring Equipment) occupies a very large bandwidth, 250 MHz in total for the uplink and downlink, though on a shared basis with military systems and some GNSS. Discrete frequencies are assigned to different ground stations, which are used by aircraft to assist navigation in en-route airspace and at airports with associated landing systems. It is also used by General Aviation to help them remain outside of controlled airspace and avoid infringements.

Pricing may be justified per ground station (Option B) if there is denial of spectrum to alternative ground-based users who would attach a value to a DME assignment. We do not see a case for pricing airborne DME users. As part of the assessment of opportunity costs required to determine the scope and levels of aeronautical AIP, Ofcom should consider the merits of applying to AIP here, in conjunction with CAA and MoD.

MLS (5030-5150 MHz) and other Navigation Aids:

There is currently limited take-up of MLS in its internationally mandated band, 5030-5150 MHz. Subject to co-ordination with neighbouring countries it should be possible to re-use some of these frequencies for alternative applications. MLS involves transmissions from the ground only so there is not the problem of aircraft entering the country and transmitting across the whole band. National reuse for other services should therefore be possible and is relevant to the calculation of AIP, which the Audit recommends should be applied to this band subject to the need not to create perverse incentives.

ILS: The propagation characteristics of the much lower frequency used by ILS compared to MLS, when combined with international constraints, limits the opportunities for implementing alternate services. AIP could still be applied to this use if there is excess demand for ground frequencies, and the Audit understands that there is a shortage.

Where there is a choice for operators to use different landing aids and navigation systems it would be preferable for the alternative options to be subject to the same incentive pricing system, with prices differing between bands depending on opportunity cost, to encourage economically optimal decision making. As outlined in Chapter 6 the Audit is recommending that there should be a review of landing systems and navigation aids to assess the scope for consolidation.

Radio Altimeters (4.2-4.4 GHz)

As set out in Annex B the allocation of 200 MHz for radio altimeters appears to be significantly more is technically needed to provide functionality. However in our view radio altimeters are not currently suitable for the application of AIP for civil or military use due to co-ordination problems and the lack of opportunity cost resulting from individual use. If pricing was imposed in isolation it could reduce use of the band but would be unlikely to deliver any benefits as reuse of the spectrum would still be prevented by any residual users based in the UK or elsewhere. However as a priority Ofcom should push for international work to evaluate the economic case, including benefits to other potential spectrum users, of a co-ordinated move to narrow the radio altimeter band internationally.

VHF Comms (117.975-137 MHz)

Channel size has been progressively reduced to accommodate increased traffic within constrained bandwidth, most recently with the start of implementation of 8.33 kHz channel spacing in place of the old 25 kHz channels. CAA's view is that the band is virtually saturated, and that the scarcity of VHF frequencies in Europe continues to potentially limit airspace capacity and efficiency. Due to congestion there is an economic case for differential pricing to encourage addition of more efficiency equipment where there is a technology choice.

Annex D

Consultations

The Audit team has engaged with a wide range of stakeholders over the course of the project. In some cases this engagement has been with those who are the subject of our review – for example the Ministry of Defence and the Civil Aviation Authority – and we are grateful for the considerable input they have provided. In other cases our contacts have been with those who may be interested in engaging with the public sector and their spectrum, for example, commercial spectrum users. In all cases the Audit team found discussions valuable and informative.

Many contacts have been made bilaterally, but the more formal consultative elements of the Audit are listed below.

1. Initial consultation letter

In March 2005 an open letter was issued, confirming the Audit's Terms of Reference and inviting interested parties to submit views or make contact with the Audit team.

2. Emerging Issues consultation document

The Audit's consultation document was published in July 2005. It set out the emerging issues identified by the Audit and invited responses to a list of consultation questions. Over twenty responses were received. Where respondents were content for the responses to be made public, these have been placed on the Audit's website at www.spectrumaudit.org.uk.

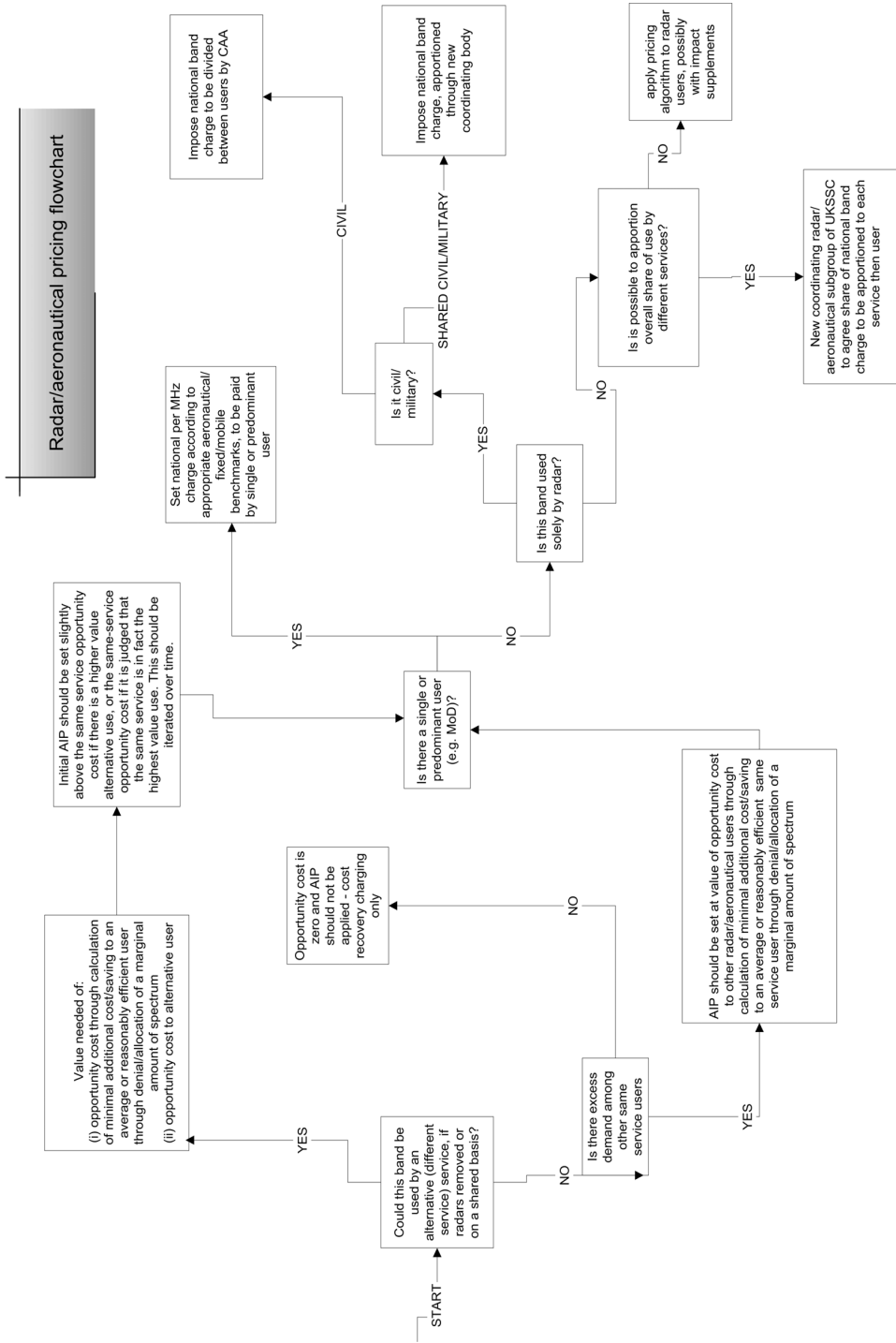
3. Seminar

The Audit team held a seminar in September 2005, which was attended by over 90 representatives from both public and commercial sectors. The sessions focused on some key issues under consideration by the Audit team: (i) market mechanisms and the public sector; (ii) bandsharing – reporting interim findings from two studies carried out for the Audit and (iii) the demand for spectrum – reporting the findings of another study carried out on behalf of the Audit. The seminar was held under the Chatham House Rule, so no formal notes of the meeting have been made.

4. International questionnaire

The Audit issued a questionnaire to a selected group of European and international spectrum regulators. Some useful responses were received, which provided valuable background information for the Audit team. The level of responses was not sufficiently high to enable aggregate results to be presented in this report.

Radar Pricing Flowchart



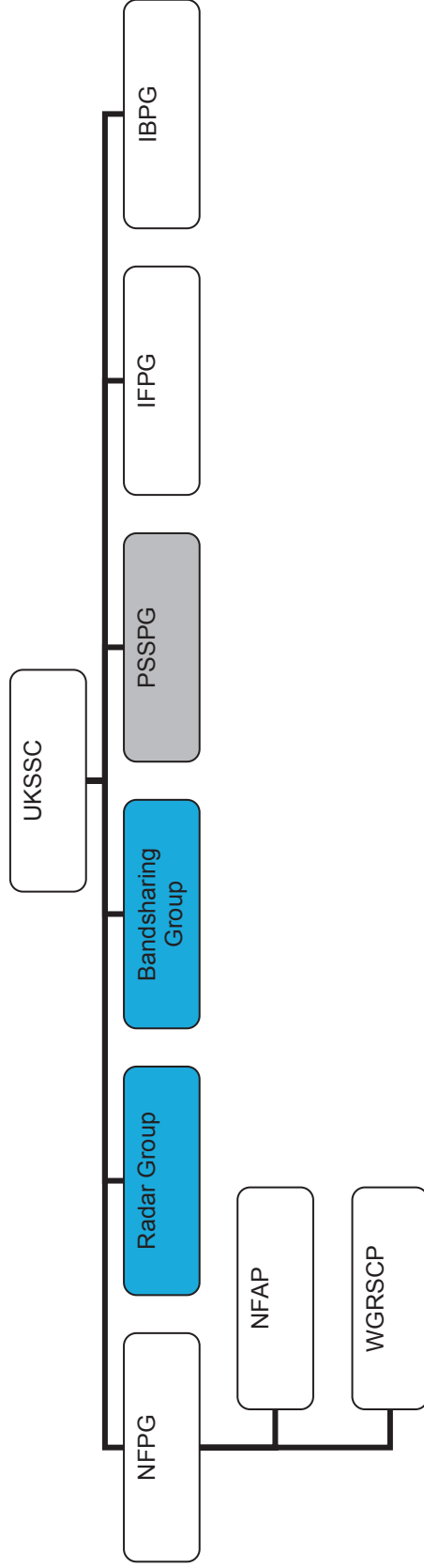
Annex F

Glossary

AIP	Administered Incentive Pricing
CAA	Civil Aviation Authority
CEPT	The European Conference of Postal and Telecommunications administrations
DME	Distance Measuring Equipment
DTI	Department of Trade and Industry
ETSI	European Telecommunications Standards Institute
GBAS	Ground Based Augmentation System
GHZ	Gigahertz (frequency of one thousand million Hertz)
GSM	The Global System for Mobile Communications
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
ITU	The International Telecommunication Union
kHz	kilohertz (frequency of one thousand Hertz)
MCA	Maritime and Coastguard Agency
MHz	Megahertz (frequency of one million Hertz)
MLS	Microwave Landing System
MoD	Ministry of Defence
MoU	Memorandum of Understanding
NATS	National Air Traffic Services Ltd
NFPG	National Frequency Planning Group
Ofcom	The Office of Communications
PMSE	Programme making and special events
PPARC	Particle Physics and Astronomy Research Council
PSSPG	Public Safety Spectrum Policy Group
PSSTG	Public Spectrum Safety Test Group
RA	Radiocommunications Agency
RNSS	Radio Navigation Satellite Systems
RRC	Regional Radio Conference
RSA	Recognised Spectrum Access
SES	Spectrum Efficiency Scheme
SOLAS	International Convention for the Safety of Life at Sea
UAV	Unmanned Aerial Vehicle
UKSSC	UK Spectrum Strategy Committee
VOR	VHF Omni-directional Range
WRC	World Radio Conference
WT Act	Wireless Telegraphy Act

Annex G

UK Spectrum Strategy Committee: Recommended Structure



Blue indicates new groups; grey indicates revised reporting arrangements

Key: UKSSC: UK Spectrum Strategy Committee; PSSPG: Public Safety Spectrum Policy Group; NFPG: National Frequency Planning Group; NFAP: National Frequency Assignment Panel; IFPG: International Frequency Planning Group; IBPG: International Broadcast Planning Group; WGRSP: Working Group on Radio Site Clearance Policy.