Exploring a new framework for defence spectrum sharing in the UK

An LS telcom study for the UK Spectrum Policy Forum

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Contact:
Mr. Saul Friedner
Director, Spectrum Services
Tel: +44 20 3740 6470
Email: SFriedner@LStelcom.com

LS telcom UK Ltd
Dowgate Hill House,
14-16 Dowgate Hill,
London EC4R 2SU
United Kingdom
Tel: +44 20 3740 6470
Fax: +49 7227 9535 605
Email: info@LStelcom.com
Internet: www.LStelcom.com

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1 Executive Summary

Crown spectrum, as opposed to Civil spectrum, is used differently and with different expectations. It cannot be viewed through a civil spectrum lens: what may seem inefficient from a civil perspective may not seem so when viewed from the crown direction. Also, over the years, spectrum that is not particularly useful for civil applications has naturally ended up under the crown, in much the same way as wide areas of moorland and natural resource has ended up being managed by the MOD. It's of no use generally for building houses, nor higher frequency high-capacity mobile coverage.

Continuing the real estate analogy, most of the good building land has been used up. The 'airfield sites' are now covered in housing and all that is left is progressively less-desirable spectrum.

This report investigates the entire Crown spectrum holding, defines certain bands that might still be of interest commercially, and describes a way of accessing this spectrum that can be actioned by Ofcom based on rules agreed by MOD.

There are other bands that could be described as 'Keep out' or 'Friends Only', the latter being suitable for specific, custom assignment, probably based on a proven international need defined by ITU requirements, such as satellite systems with worldwide applicability. PMSE, also, is a proven methodology for short-term, often repeated assignments that use all available spectrum, but specifically large amounts of shared spectrum in the higher frequency bands for cameras. We do not propose to change this arrangement, but we do propose that any new sharing methodologies recognise useful past or repeated PMSE assignments and avoid denying access to them in the future if possible.

The study explored existing demand from civil users across mobile, fixed links, satellite, PMSE and utilities to understand the extent of interest in using MOD spectrum. It found there was not extensive demand but interest in specific portions and challenges in accessing it in a coherent and appropriate way. This demand was considered as the primary driver for determining the size and shape of the future defence spectrum sharing framework but acknowledging that framework should also be able to support some new use or frequency band identified in future.

The study proposed four scenarios seeking to identify one that would best align with MODs requirements. The study assessed and summarised them as follows:

- **Maintain the status quo**: This works at the moment – but fails to address the specific MOD desire to formalise and enhance today's approaches to sharing spectrum in the UK.
- **Extension of the principles of Ofcom's SAL**: Ofcom's vision for the SAL framework, including harmonisation and standardisation, and the benefits of one body to handle access to spectrum for all civil spectrum users has much to commend. Extending the SAL to include non-IMT uses, and the technical requirements for managing more complex coexistence scenarios and operation of licences with different conditions of duration and use (including terminating use at short notice) are a significant deviation from existing practice.
- **Automated Dynamic Spectrum**: There is significant overhead (and cost) in developing a DSA system to perform this task. An overhead would be imposed on all civil devices seeking to operate within this regime. MOD would need to monitor / assess short term use and develop methods to preclude 'bad actors' gaining insight into their activity.
- **MOD as an SMO**: This option is more strategic that the other 3. Strategic aspects of this option could justify its adoption irrespective of demand – but would impose additional burdens on MOD, and possibly Ofcom.

Overall, given the multi-dimensional aspects and the close collaboration that would be essential amongst key players for developing such a sharing framework, the study determined that there are still too many uncertainties to advocate a strong preference for any preferred solution, it is likely that there

are key aspects which will require consideration by, inter alia, DSIT, MOD and Ofcom, before significant clarity on a preferred direction could be established.

Nevertheless, the study makes a number of recommendations based on the analysis undertaken and findings which are summarised as follows:

Demand for MOD spectrum and existing sharing:

- We recommend that any expansion to other uses or applications can only be merited if there is sufficient demand, and any expansion should be incremental.
- We recommend that the level of demand for access to MOD spectrum by any new users (ie not PMSE, Radio Amateur or Fixed Links) be verified, possibly by Ofcom.
- We recommend that any change to the sharing regime should not prejudice existing sharing.
- We recommend that information gathering begins before any implementation to assess the credibility of the demand for the restricted availability of spectrum (for a prolonged period) that would exist in MOD spectrum
- Ofcom should review the benefits, or otherwise, of streamlining/integrating sharing approaches into a common framework.

Licence application process:

- We recommend that Ofcom should be clearly identified as the body that manages access to MOD spectrum for civil users, and for all users (civil and Crown) for access to civil spectrum.
- We recommend that Ofcom should monitor and publish any applications for spectrum that are unable to be supported in order to assess if any improved sharing in MOD spectrum is a priority.
- Any required coordination between MOD and Ofcom can and should be handled between them, and their decision on sharing conditions would be provided to the applicant – not the rationale. This will provide MOD a level of protection and security.

Sharing between civil and Crown users:

- We recommend that MOD develop a comprehensive spectrum roadmap identifying current and future use. This will consider potentially long military equipment lifecycles, emerging technologies, operational needs, and international regulatory developments such as WRC27.
- We recommend the identification and formalisation of the roles within Ofcom and MOD involved in managing and maintaining any new framework.
- We recommend that Ofcom and MOD identify spectrum constraints and agree methodologies to allow sharing. This will include building up a set of sharing rules or coexistence approaches that Ofcom can utilise in assessing suitable sharing arrangements.
- UK MOD to continue to widen engagement with other government agencies, private stakeholders, and academia to advance and monitor development of sharing technologies

Benefits of harmonisation and providing inputs to international meetings:

- We recommend that, MOD and Ofcom remain active in regulatory and policy fora and seek to incorporate agreed best practice in future sharing frameworks.
- We recommend that MOD share the outcomes of this study with friendly/NATO countries and acknowledge the parallel work within CEPT that could yield benefits to the wider defence community in the same way but considering key defence requirements.
- We recommend that sufficient resources (both Ofcom and MOD) should be put in place to support planning and analysis for WRC27.

2 Introduction

This study considers the future of spectrum sharing between civilian and military users in the UK. The UK Spectrum Policy Forum (UK SPF) has commissioned this work to investigate potential improvements in sharing access to UK Ministry of Defence (MOD) spectrum for civilian users.

The study is built on the premise that the proposed civilian/military sharing scenarios are considered and analysed in the context of a non-war, peacetime period.

The key objective is to identify an appropriate framework that easily facilitates future sharing: enabling civilian access while allowing Defence to meet its present and future strategic needs. We have endeavoured to gather as much relevant information as possible, within the study timeframe. However, due to the nature of MOD activities, not all information can be disclosed.

A significant proportion of the information was gathered from civil stakeholders including from the mobile industry, utilities, PMSE, satellite and rural broadband sectors. We have also engaged with Ofcom and DSIT. We also organised a workshop with the MOD dedicated to capturing spectrum use across key bands and understand the current processes for sharing spectrum and collaboration with Ofcom.

The report is structured as follows:

- Section 2 provides and introduction and domestic and international context for spectrum sharing
- Section 3 provides additional context to and spectrum management and sharing in the UK
- Section 4 explores and assesses future civil demand for MOD spectrum
- Section 5 offers a comprehensive summary of MOD spectrum usage and future demand
- Section 6 explores potential candidate bands for potential sharing between military and civilian stakeholders
- Section 7 puts forward considerations and barriers for a new framework
- Section 8 develops recommendations and matters for further considerations

The remainder of this section provides an overview of the domestic and international contexts within which this study is conducted.

2.1 Domestic context

The case for understanding the issues related to sharing spectrum with defence applications is timely. It comes at the end of the Public Sector Spectrum Release (PSSR) Programme, which became in the early 2000s the de facto means to make available any spectrum that could be released for private sector use.

Going forward, the UK Ministry of Defence (MOD) does not anticipate the permanent release of frequencies it uses due to the increasingly congested spectrum environment it operates within at home and internationally. However, MOD has expressed interest in facilitating additional private and commercial access to its spectrum holdings when /where it is not needed by adopting a more agile and suitable framework.

UK MOD recognises that economic growth, which includes the need for commercial spectrum access to military, is in the national interest of the United Kingdom. Enabling greater civilian use of defence spectrum, however, often conflicts with national security interests. Therefore, spectrum sharing has become a critical priority for UK MOD.

Spectrum sharing is also a central component for both DSIT and Ofcom's current and future direction. This is evidenced in the following documents and activities:

- DSIT Spectrum Statement[1]
- Ofcom, Spectrum strategy[2]
- DSIT Wireless Infrastructure Strategy[3]
- Ofcom Spectrum Roadmap[4]
- Ongoing spectrum sandboxes projects[5]

2.2 International context

Internationally, there is a growing focus towards embracing spectrum sharing. The introduction of the Citizens Broadband Radio Service (CBRS) in 2020 in the US set a precedent for defence-managed spectrum sharing approaches and showed coexistence was possible through a system that protects defence users while enabling commercial mobile service.

CBRS's three tier approach is, so far, the most advanced and direct example of dynamic spectrum sharing between government and commercial users. It is also worth noting that the CBRS model is highly specific to the US spectrum environment and mobile market.

The first layer is for incumbent users, predominantly the US Navy, but could also be other government departments. The second layer is for the priority access layer (PAL) and these users could be mobile operators, industrial users, or emergency services for example. The third (bottom layer) tier users are for General Authorised Access (GAA) which could be local area networks, in-building networks, routers, and residential and enterprise networks.

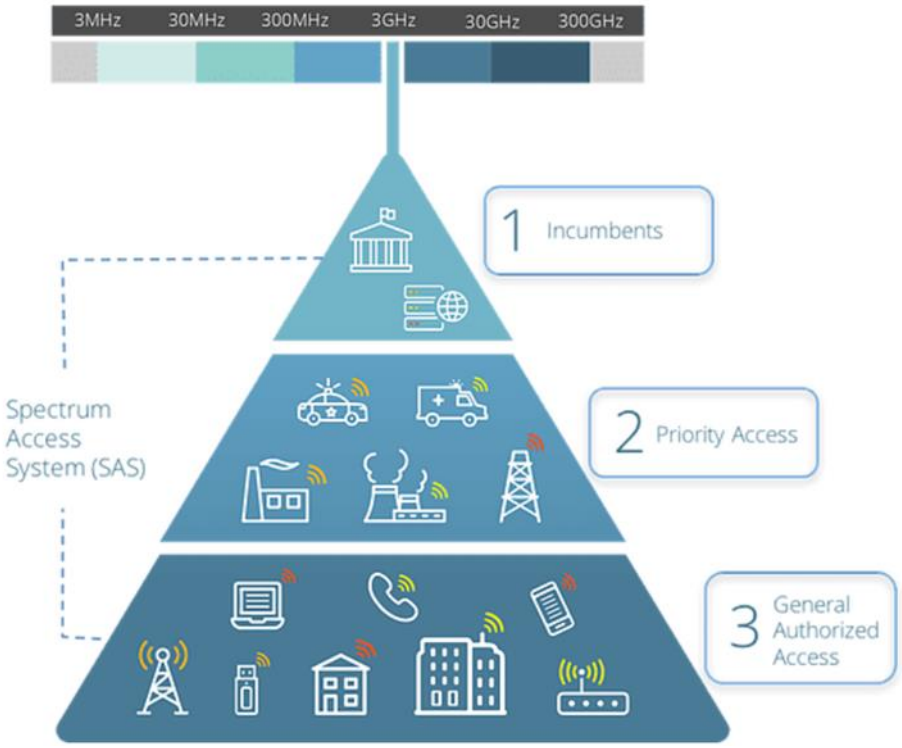
[1] UK DSIT Spectrum Statement. DSIT Policy Paper, 2023 https://www.gov.uk/government/publications/spectrum-statement/spectrum-statement [Accessed 18 June 2024]

[2] Ofcom Statement, Supporting the UK's wireless future: Our spectrum management strategy for the 2020s, 2021 https://www.ofcom.org.uk/siteassets/resources/documents/consultations/category-1-10-weeks/208745-supporting-the-uks-wireless-future/associated-documents/spectrum-strategy-statement.pdf [Accessed 18 June 2024]

[3] UK DSIT, UK Wireless Infrastructure Strategy, Policy paper, 2023 https://www.gov.uk/government/publications/uk-wireless-infrastructure-strategy/uk-wireless-infrastructure-strategy [Accessed 18 June 2024]

[4] Ofcom, Spectrum roadmap: Delivering Ofcom's Spectrum Management Strategy, 2022 https://www.ofcom.org.uk/spectrum/innovative-use-of-spectrum/delivering-ofcoms-spectrum-management-strategy/ [Accessed 18 June 2024]

[5] See https://uktin.net/whats-happening/news/everything-you-need-know-about-spectrum-sandboxes



Source: Ongo Alliance

Figure 1: CBRS three-tiered system

We have learnt from our stakeholder engagement that other countries, such as Germany, Australia, among others, are assessing different options and mechanisms to enable access in military-used frequency bands.

Late last year, WRC-23 agreed a WRC-27 agenda that considers three wholly or partially[6] harmonised NATO bands for IMT. WRC-27 Agenda Item 1.7 considers sharing and compatibility studies to develop technical conditions for the use of International Mobile Telecommunications (IMT) in the following frequency bands:

- 4400 – 4800 MHz
- 7125 – 8400 MHz[7] (or parts thereof),
- 14.8 – 15.35 GHz

This means that a revised defence sharing framework could be in place, in the UK, before a decision is made at WRC-27 with regards to these frequency bands.

[6] Under ECA table, 7.125-8.400 GHz, only the portion 7.250-7.750 GHz and 7.900-8.215 GHz under footnote ECA36

3 MOD spectrum sharing context

3.1 Historical Background

Traditionally the public sector, and the UK Ministry of Defence (MoD) in particular, has had secure access and use of a large amount of spectrum. In 2002, the increasing spectrum demand from all users and seeking encouragement of efficient use, prompted Martin Cave[8] to recommend market-based methods of assignment (primarily for non-public spectrum users). Subsequently, a second study addressing public sector spectrum holdings was completed in 2005[9]. This called for the introduction of incentive pricing for public bodies and a plan for the release of a large amount of public sector spectrum holdings.

Cave's recommendations motivated the Public Sector Spectrum Release (PSSR) Programme, which became the de facto means to make available any spectrum that could be released for private sector use. This PSSR programme had an initial target of releasing at least 500 MHz of spectrum below 5 GHz for private sector use. Following the extensive demand from civilian users, the original target was increased in 2016 to 750 MHz.

In 2023, DSIT reported[10] that the initial PSSR programme ended in December 2022, having released or shared 687MHz of spectrum previously used exclusively by the public sector. At the time of writing, the final report on the PSSR programme has not been published but it is expected to be released soon. This same policy statement noted: "Identifying further spectrum will be more challenging since the earlier release of spectrum necessarily resulted in transferring systems in those bands into the remaining spectrum used by the public sector."

What's Next?

The first phase of the PSSR Programme effectively identified public sector spectrum for release, but further release will be more challenging due to extensive use by incumbents. As noted by DSIT[11], "the next phase of the initiative on public sector use of spectrum should be done on a demand-led basis rather than a fixed release target and facilitated via the full release of spectrum or through sharing as appropriate. This will entail a focus on investigating potential future demand from commercial applications and identifying candidate frequency bands used by the public sector for release or sharing."

3.2 Spectrum Management in the UK

Ofcom manages the radio spectrum within a statutory framework created by the Communications Act 2003 (the 'Communications Act') and the Wireless Telegraphy Act 2006 (the 'WT Act').

[8] The Cave Review. Treasury Report. Independent Review of Spectrum Management. 2002.

[9] The Cave Audit. Treasury Report. Independent Audit of Public Sector Spectrum Holdings. 2005.

[10] UK DSIT Spectrum Statement. DSIT Policy Paper, 2023 https://www.gov.uk/government/publications/spectrum-statement/spectrum-statement [Accessed 18 June 2024]

[11] ibid

The 2003 Communications Act[12] established Ofcom's duties as the consolidated Communications regulator in the UK and conferred legal authority for Ofcom to perform them. Ofcom's principal duties are defined to be to:

- further the interests of citizens in relation to communications matters; and
- further the interests of consumers in relevant markets, where appropriate by promoting competition.
- In relation to radio telecommunications matters, by virtue of the above, Ofcom is required to secure:
  - optimal use for wireless telegraphy of the electromagnetic spectrum;
  - availability throughout the United Kingdom of a wide range of electronic communications services.

The 2006 Wireless Telegraphy Act[13] establishes Ofcom's obligations and powers to regulate radio spectrum, including the managing and monitoring of spectrum use, licensing and granting spectrum access, enforcement rights and the regulation and approval of radio equipment. The Act differentiates between the grant and a licence of spectrum use. Grants can be made to holders of a wireless telegraphy (WT) licence[14,] recognised spectrum access (RSA)[15] or to any other entity that Ofcom deems appropriate.

Consequently, Ofcom is the only body that has power to grant radio spectrum licences. The WT Act, however, does not bind the Crown so Crown bodies[16], do not require authorisation and licence to use radio equipment.

Public sector bodies have to some extent responsibilities and roles in spectrum management, including making decisions on public holdings. In practice, both Ofcom and MOD cooperate in a way that does not intentionally cause interference to military and civilian users.

As noted earlier, Ofcom previously managed auction award processes of previously held public sector spectrum holdings. In addition, any civilian user sharing access to public sector spectrum would require a WTA licence.

As required by the WT Act, from time to time, Ofcom publishes the UK Frequency Allocation Table[17]. Section 2 explains the UK Footnotes on the considerations and restrictions on use that are applied in

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[12] Communications Act 2003. UK public general Acts with revisions. https://www.legislation.gov.uk/ukpga/2003/21/introduction [Accessed 1 June 2024]

[13] Wireless Telegraphy Act 2006. UK public general Acts with revisions. https://www.legislation.gov.uk/ukpga/2006/36/introduction [Accessed 1 June 2024]

[14] WT licences define the conditions under which civil users may use apparatus which transmits electromagnetic waves. Some apparatus is explicitly exempted from needed a licence, such as mobile handsets, wi-fi equipment (so-called, licence exempt devices), and television receivers.

[15] RSA protects an area so that only authorised users can operate in a given area. This can protect a receiver (e.g. a radio telescope) from UK-based transmissions, even in the desired signal to be received emanates from outside of the UK (e.g. space).

[16] It is important to note there is is no legal definition of a Crown body but central government departments reporting to ministers such as the Ministry of Defence and Home Office are generally considered to be Crown bodies. There are other users usually understood to be public sector, such as local government, that use spectrum via Ofcom licences.

[17] United Kingdom, Frequency Allocation Table. Ofcom. 12th January 2017. https://www.ofcom.org.uk/__data/assets/pdf_file/0016/103309/uk-fat-2017.pdf [Accessed 1 June 2024]

different frequency bands. It is noted that footnotes beginning with a 2 (e.g. UK2.1) apply to bands where the 'responsibility for granting permissions to use frequencies in this Allocation rests with Defence'. UK3.xx is used for bands where 'responsibility for assigning frequencies to this Allocation rests with Ofcom' and are for Emergency Service use. UK4.xx are for airborne use under the auspices of the Safety and Airspace Regulation Group (SARG), where the CAA licences (civil users) and co-ordinates (military users) spectrum use.

In the UK, civilian users, such as Programme Making and Special Events (PMSE), have shared access to spectrum for a long time – and many of the high-profile large public events (such as the London Olympics, Glastonbury, or Formula 1) have been facilitated by the MOD and Ofcom coordinating access to "Footnote2" spectrum. These are coordinated on an event-by-event basis. This is undertaken on a case-by-case basis for when civil users have expressed an interest in accessing specific MOD bands. Longer term sharing is also agreed with many different applications, with specific restrictions on the location of use (or non-use) and power levels[18].

3.3 Sharing approaches in the UK

Effective sharing requires consideration of both the legal and regulatory aspects under which spectrum rights are authorised or withdrawn (the governance and control) and the technical aspects that support decision-making and ensure that the interference environment is acceptable to all parties.

Thus, Ofcom's existing Sharing Framework[19] provides a useful baseline to identify and support new potential sharing opportunities, including public sector spectrum. The aim of the framework is to ensure that sharing options are considered systematically in all spectrum authorisation. It mostly consists of three key elements:

- Characteristics of use for both incumbents and prospective users;
- Barriers that may limit the extent of current and future use; and
- Regulatory tools and market and technology enablers that could facilitate new opportunities for increased and more intense sharing.

The framework paved the way for the introduction of the Shared Access Licences (SAL) for localised access to a number of bands that support mobile technology (including 1800 MHz, upper 2300 MHz, 3800-4200 MHz, and lower 26 GHz) and the Local Access Licences (LAL), which facilitate access to unused mobile operator-licensed spectrum.

The table below shows the approach and process under the current SAL framework.

[18] Frequency sharing arrangements between civil and military services. Ofcom Publication. 19 August 2022. https://www.ofcom.org.uk/__data/assets/pdf_file/0020/103295/fat-civil-military-sharing-arrangements.pdf [Accessed 1 June 2024]

[19] Ofcom, A framework for spectrum sharing, 2016 https://www.ofcom.org.uk/siteassets/resources/documents/consultations/uncategorised/7844-spectrum-sharing-framework/summary/statement.pdf [Accessed 1 June 2024]

Table 1: Process under current SAL scheme

- New users will apply to Ofcom to get licences for the locations, bands, and bandwidths that they need to provide their service
- Ofcom will assess applications to see if any interference would be caused to, or received from, other licensees in the band
- Ofcom will grant individual licences for the requested locations, bands, and bandwidths on a first come, first served basis, provided that the application passes this coordination process.
- Users will pay licence fees to Ofcom, which are due annually

This scheme has enabled a wide range of users and applications (e.g. private networks, WISPs) to access to access spectrum supported by mobile technology. Ofcom have issued more than 1600 licences under this scheme since 2016 and consider the initiative to be a success.

According to daily updated licence data, there are just under 950 live licences as of July 2024 according to daily updated licence data. Table 2 details the number of live SAL licenses registered with Ofcom under the Wireless Telegraphy scheme (as of July 2024), categorized by band and year of license issuance.

Table 2: Live SAL licences as of July 2024

						Issued					
Shared Access Licence Type	**1800 MHz**	**2300 MHz**	**3.8 GHz**	**26 GHz**	**Total**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low Power	223	29	241	1	494	22	18	152	82	69	122
Medium Power	120	0	331	0	451	0	17	167	71	139	57
Total	**343**	**29**	**572**	**1**	**945**						

3.3.1 Review of the SAL Framework

In March 2023 Ofcom issued a call for input as part of a consultation on the Shared Access Licence framework. In the call for inputs, Ofcom stated that based on "emerging use cases, growing demand and broader international developments, we consider the time is right to reflect on user experiences in the Shared Access bands, and explore opportunities for further evolving our approach based on stakeholder feedback and the usage data we collect from licensees". Ofcom's Statement on the consultation is still pending. It is useful to consider the response from stakeholders, in particular the **University of Strathclyde (UoS)**, to this call for inputs to identify the concerns that one high profile user and an integral partner in the Sandbox initiative has identified.

In response to Ofcom's call for input:

- Overall, the UoS is supportive of Ofcom's Shared Access Licence Framework, noting: "The Shared Access Framework has been an enabler for a number of innovative applications and use cases beyond the well-established public mobile services. Our experiences working with partners in a number of countries such as New Zealand, Denmark, Ireland, and several countries in Africa show that Ofcom has established a globally leading position in innovative approaches to spectrum access."
- The UoS question if the 'first come-first served' approach to spectrum assignment could prevent access to other potential spectrum users, with little certainty that existing users are fully utilising their assignment

- UoS note that the 'ad-hoc' nature of dealing with exceptional circumstances can be problematic (when used for a traditional PMSE-type application). At the same time, UoS questions if there is sufficient flexibility in the power limits that are applied as part of the existing SAL framework.
- UoS notes that the "details of the coordination approach are not particularly well known or understood" and suggests that "a more accurate assessment of interference to be made and could potentially lead to better overall spectrum utilisation" if aspects such as antenna pattern were incorporated in the interference assessment.
- UoS questions the effectiveness of the existing licence application process: "Our experience of the current licensing process, based mainly on that of several of our project partners, suggests that it's not particularly straightforward and it takes a relatively long time to hear back from Ofcom with a response".

Ofcom's initiative to review the Shared Access Framework demonstrates confidence in the opportunity to adapt the existing framework to further improve spectrum access. The benefits of adopting a harmonised method of providing access to shared spectrum apply between nations – but also within the UK between all potential users of spectrum. It is likely that some of Ofcom's questions in the Call for Inputs could be generalised to identify the best adaptations that may also be able to harmonise access to spectrum users of both civil and public sector spectrum.

Athonet, now an HP company, provide mobile core networks to support private 4/5G networks. Their spectrum related comments are concerned with allowing relaxing restrictions on SAL power levels and ensuring that UL intensive data transfer can be supported.

BBC quote use of low power 5G private networks to support programme making and call for more flexibility in accessing 3.8-4.2 GHz band. They note that content production often has short duration and also short lead times. The BBC notes that under the current SAL: *"Application times of 42 days, a minimum licensing period of a month and no means of applying ahead of time for a future start date are anachronistic and spectrally inefficient"*. The BBC seeks that the SAL can migrate to be more like the PMSE licensing regime *"where spectrum can be licensed instantaneously online or manually within 72 hours, a similar approach for SA licences would be particularly welcome"*. The BBC notes that improved spectrum utilisation could be achieved: *"it isn't clear how co-ordination is carried out and we are concerned that an overcautious approach is taken. Reliance on rural vs urban locations appears a crude distinction given the availability of detailed terrain and urban clutter data to use instead when analysing compatibility"*. It is clear that the BBC anticipates applying success of access to spectrum that can support private networks in additional bands: *"The BBC would be very interested in discussing access to the MoD range 2300- 2350MHz for content production particularly given other long and mutually beneficial spectrum sharing arrangements that exist between the military and PMSE"*. It is likely that there will be calls to expand sharing to any bands that are given an IMT designation at WRC27.

The Dynamic Spectrum Alliance support Ofcom's SAL initiative and called for it to be enhanced with automatic and faster spectrum grants, improved co-existence modelling, and adoption of additional bands. Contrary to Athonet, they identify concerns if outdoor power limits are increased. This is probably because of the different target operating environments.

Nokia supports Ofcom's SAL, noting: *"At Nokia, we recognise Ofcom's initiative to promote digital innovation becoming the first regulator within CEPT to have developed a Shared Access Framework. This has also been recognised from CEPT, with ECC PT1 proposing to use the UK Shared Access Framework in the 3.8-4.2 GHz band as the baseline for the studies towards the EC Mandate for 3.8-4.2 GHz local area connectivity."* Nokia states that improvements could include use of higher EIRP, and that *"introducing more realism in the coordination process are some of the are elements that won't only improve efficiency in the use of the Shared Access Bands, but also enable the ecosystem to further develop to address the emerging use cases, while also making the deployment of networks in this band more affordable."*

Taken together, the consultation responses support the sharing initiative and note possible improvements in improving the process (faster, more accurate determination of interference to allow more intensive use". The coordination of IMT-type devices with other IMT-type devices (even with different TDD duty cycles, powers, and antenna patterns) is much simpler than coordination of a generic technology with the host of uses in MOD spectrum and highlight the technical challenge in seeking to promote sharing with the MOD. Any increased sharing with the MOD may benefit by a progressive introduction of technologies or geographical areas where there is likely to be the most benefit.

3.3.2 Ofcom's approach of dynamic sharing ("2023 Discussion Paper")

Ofcom's 2023 discussion paper presents a useful overview of Ofcom's position on the opportunities for future spectrum sharing, steps to explore practical applications of databases (particularly the Sandbox programme) and enabling technologies. These are discussed in turn, below.

- Opportunities for sharing: The discussion paper recognises that different sharing solutions are likely to be more appropriate for different types of users, depending upon inter alia existing spectrum holding, benefits and costs of accessing different spectrum and the quality of service requirements.
- Optimal sharing: The discussion paper recognises that 'dynamic spectrum sharing' is not predicated upon database use, such as device sensing such as DFS employed in Wi-Fi to avoid radar interference. The paper also recognises that agreements or a database can provide clarity/certainty on spectrum availability, with database use facilitating more dynamic availability – but at a cost.
- Guaranteed, time limited use: The discussion paper identifies that specific users do not require spectrum access at all times, but may need a high QoS for specific time intervals and recognises that PMSE and Radio Astronomy fit this category
- QoS tolerant users: The paper identifies that some users are able to be tolerant of lower quality spectrum, or less certain access to spectrum, but typically where these users already have a highly reliable spectrum holding and seek the additional spectrum as a 'top-up'.
- Information and technology development: The discussion paper helpfully identifies the benefits of improved (and valid) knowledge of the interference environment and spectrum use (for dynamic management) and the benefits of sharing being part of standard-based sharing.
- Standardisation: The discussion paper notes that standardisation has opportunity to improve conditions for sharing in several ways. Collection and sharing of data at the device useful to inform sharing (and ideally, able to be applied across different devices), including cooperation between standards bodies. Standardised methods and data exchange between equipment and an intelligent spectrum controller or database with adoption of open APIs.

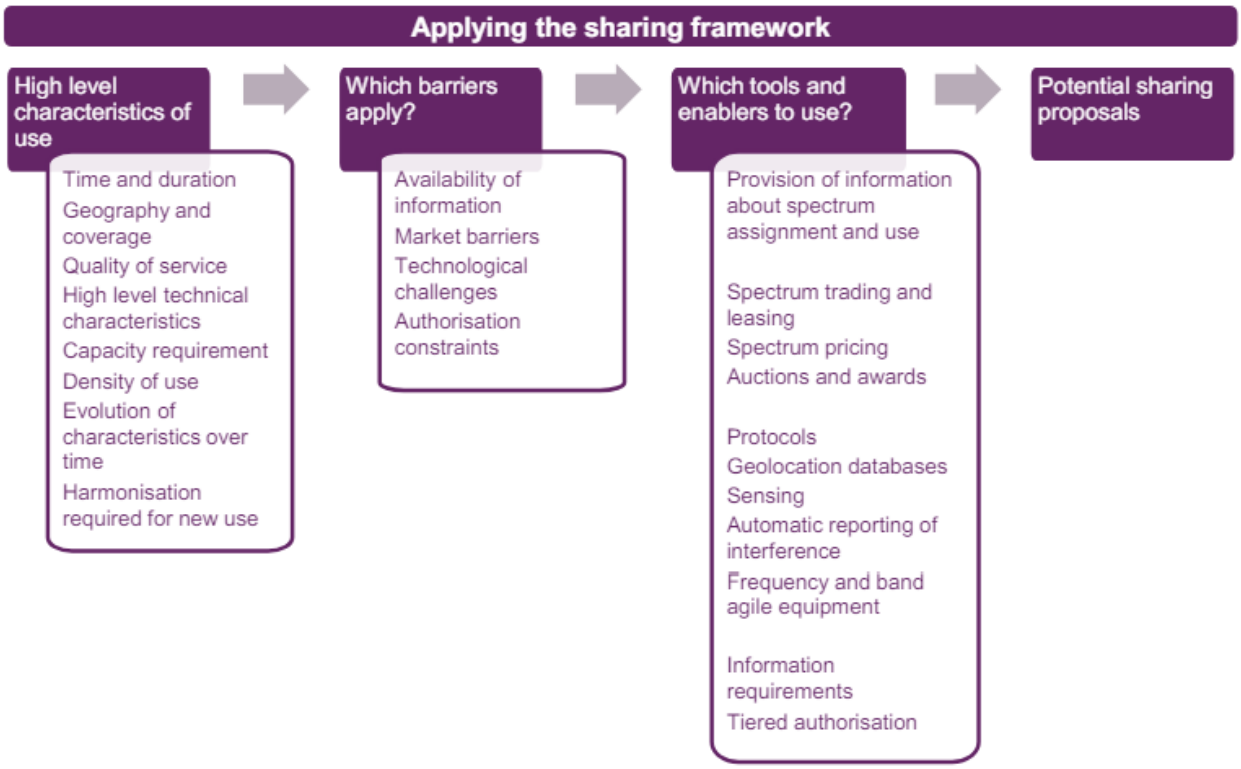
Ofcom's paper recognises the opportunities for (more dynamic) sharing and the key benefits of establishing a standardised ecosystem of communications devices and open interfaces for any intelligent spectrum controller. These innovations in communications devices are likely to be much more easily adopted in equipment with a large market, a high level of standardisation effort and fast equipment replacement cycles, such as Wi-Fi and IMT devices. Many traditional MOD applications (e.g. radar) are unlikely to adopt these until the approach has been proven and established. Ofcom's paper does specifically mention shared access with MOD and other users; it highlights particular suitability to 'top-up' users and users who seek guaranteed quality, but for specific time limited use. Ofcom highlights how a more dynamic method of managing spectrum could increase the efficiency of such spectrum use[20].

In developing potential scenarios and considerations for a potential new framework that could accommodate military and civilian sharing, we used as a reference Ofcom's Spectrum Framework methodology as shown in Figure 2 below. Initially, we examined the characteristics and demands of both

[20] This improved efficiency would only be achieved if there is demand for the spectrum that would require this capability and justify the overhead in developing the dynamic sharing system.

incumbents (military) and prospective users in sections 5 and 4. We then assessed the barriers, both technical (explained in section 6) and non-technical (covered in section 7). Additionally, we conducted a cross-sectional analysis of these factors as discussed in section 8.

It is important to note, as illustrated in Table 3, that the Ministry of Defence (MOD) has specific and often more stringent requirements for spectrum sharing. This is primarily due to the critical and sensitive nature of its operations, which include national security, emergency response, and military communications. These requirements necessitate careful consideration and management of spectrum usage to ensure reliability, security, and effectiveness in fulfilling its operational mandates.



Source: Ofcom

Figure 2: Process for identifying potential sharing opportunities under Ofcom's sharing framework

4 Overview of civil demand

The following assessment of civil and private demand has been informed by a series of interviews conducted with UK stakeholders, including Ofcom, DSIT, MOD, DEMA, vendors, mobile operators, utility companies, satellite operators, IoT, PMSE and other regulatory and policy organisations, as well as publicly available information.

For each of the sectors below, we have:

- Summarised a high-level overview of the historical context and active and future trends;
- Assessed future demands for access to MOD spectrum and access conditions.

Future demand

During our consultation with stakeholders we have noted that there is limited interest from civil and commercial users for access to Crown frequencies on a shared basis. Primarily, this is because of necessary technical conditions placed by the MOD on the particular shared usage that diminishes interest in accessing the bands for some types of users.

As mentioned previously, well- established and documented sharing arrangements already exist between the MOD and certain civilian users, such as PMSE, amateur and/or fixed links. Similarly, we believe that additional future demand for defence spectrum sharing would be quite niche and specific, currently limited to a few stakeholder groups. The demand we have identified in the consultations is as follows:

- Stakeholders that hold licences in adjacent bands and seek to expand current holdings for various reasons. For instance, this may include utilities seeking access to additional spectrum in the10.5 GHz band; and/or a mobile operator with a licence in the upper 2.3 GHz looking to secure access in the lower part of the band;
- Stakeholders seeking access to spectrum for a limited time in a limited geographical zone, such as PMSE. Demand of this nature is expected to continue if not increase, as detailed in section 3.5;
- Other stakeholders, such as satellite IoT and or agritech applications, that may require access to MOD bands either due to international allocation or their unique operational profile and have not been able to do so under the current arrangements. These users may be able to tolerate non-availability of clean spectrum at all times.

We acknowledge the upcoming discussions on military bands at WRC-27 (World Radiocommunication Conference 2027) and the potential identification of new bands for International Mobile Telecommunications (IMT) in the future. These developments could have a significant impact on the demand for MOD spectrum in the coming years, as stakeholders strive to find suitable spectrum for 6G, although this would again be subject to international agreement and hardware support.

If a sharing framework were to be in place, that itself can build trust and facilitate access in the future to mobile bands, driving future demand.

The importance of device ecosystems

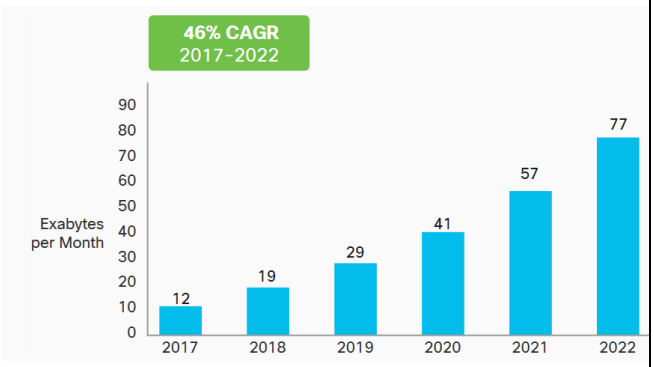
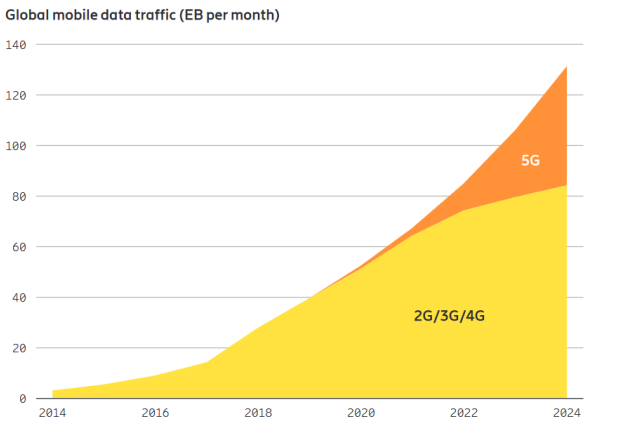
An overarching theme that emerged from our stakeholder interviews was the critical importance of the hardware and international regulatory ecosystem. Across the board, stakeholders emphasised the necessity of harmonising spectrum usage on a regional or global scale for successful implementation and cost efficiency gains.

These factors will be especially crucial in the future, as we explore candidate bands for potential sharing (discussed later in this document). Examining the potential for spectrum harmonisation will be a critical step in maximising the success of future spectrum sharing initiative.

4.1 Mobile

Trends and historical context

Since around 2007 (introduction of the iPhone and smartphones generally), there has been significant, consistent, and rapid increase in mobile data traffic consumption. This mobile traffic growth has been regularly reported and analysed by major telco vendors, trade associations (including the GSMA,) analysts, regulators and research organisations leading to a continued demand for mobile spectrum. Examples of these historical demand forecasts are shown below in a period of relatively strong growth between 2019 and 2022.

Cisco VNI[21] (2019)	Ericsson Mobility Report[22] (2019)
	
Analysys Mason[23] (2019)	Ofcom[24] (2022)

[21] Cisco VNI, 2019 http://media.mediapost.com/uploads/CiscoForecast.pdf

[22] Ericsson Mobility Report 2019 https://recursos.bps.com.es/files/914/28.pdf

[23] Analysys Mason: Wireless network data traffic worldwide trends and forecasts 2019-2024 https://www.analysysmason.com/globalassets/x_migrated-media/media/analysys_mason_wireless_traffic_forecast_sample_apr2019_rdnt03.pdf

[24] Ofcom, Mobile networks and spectrum meeting future demand for mobile data 2022 https://www.ofcom.org.uk/siteassets/resources/documents/consultations/category-3-4-weeks/232316-meeting-future-demand-for-mobile-data/associated-documents/secondary-documents/discussion-paper-meeting-future-demand-for-mobile-data

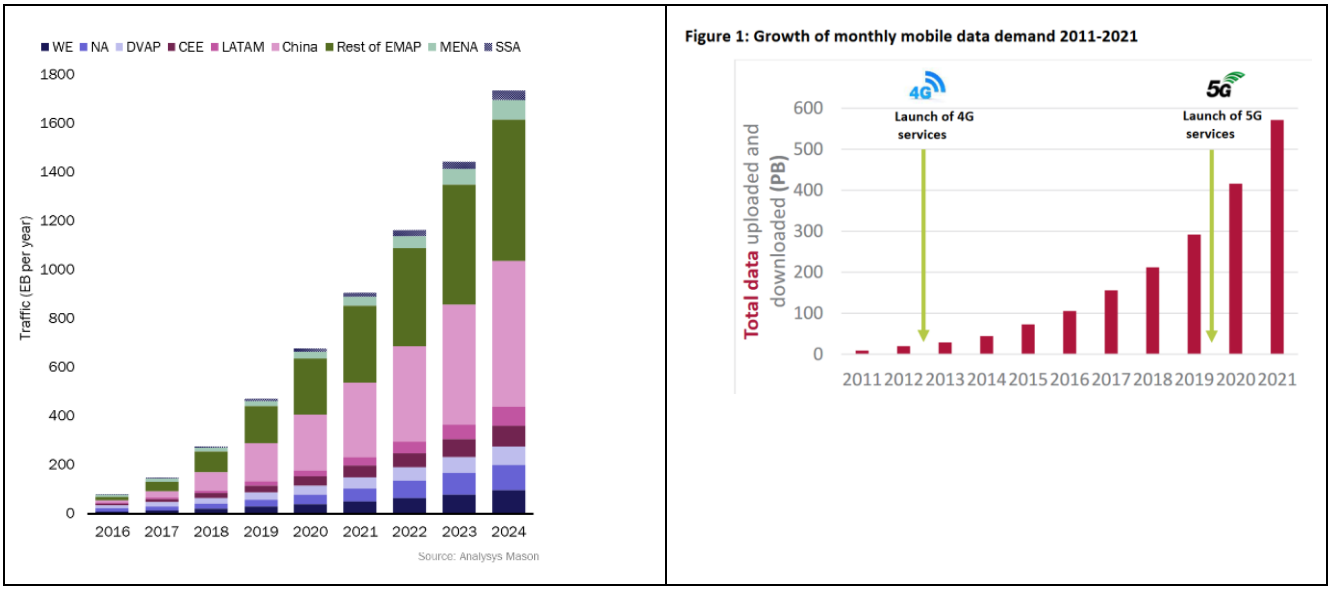


Figure 3: Example mobile data traffic growth forecasts from around 2019-2022

This continued growth in mobile data traffic was one of the main drivers for the implementation of the PSSR programme. As mobile data usage surged, there was a corresponding need for additional dedicated spectrum to support such demand, which subsequently led to the release and auction of public sector frequencies (primarily MOD, and Home Office) for mobile use.

More recently, there have been some indicators, pointing towards a global slowdown in the rate of growth in mobile data demand, despite continued expansion. According to Ofcom's Connected Nations report[25], from 2022 to 2023, total monthly mobile data traffic in the UK experienced an annual growth of around 25%, lower than the approximately 27% reported the previous year. Although a small decrease in growth in this single metric case, it could be argued that this is the first sign of a stabilisation in the rate of growth.

This has also been identified by regulators in other major markets and industry reports[26]. More recently, Ericsson's Q2 2024 Mobility report[27], also published a downward adjustment in their mobile network data traffic numbers for the second half of 2023. While there is some uncertainty about the exact pace of mobile traffic growth in the future, the industry anticipates continued expansion, albeit at a potentially slower rate than initially anticipated.

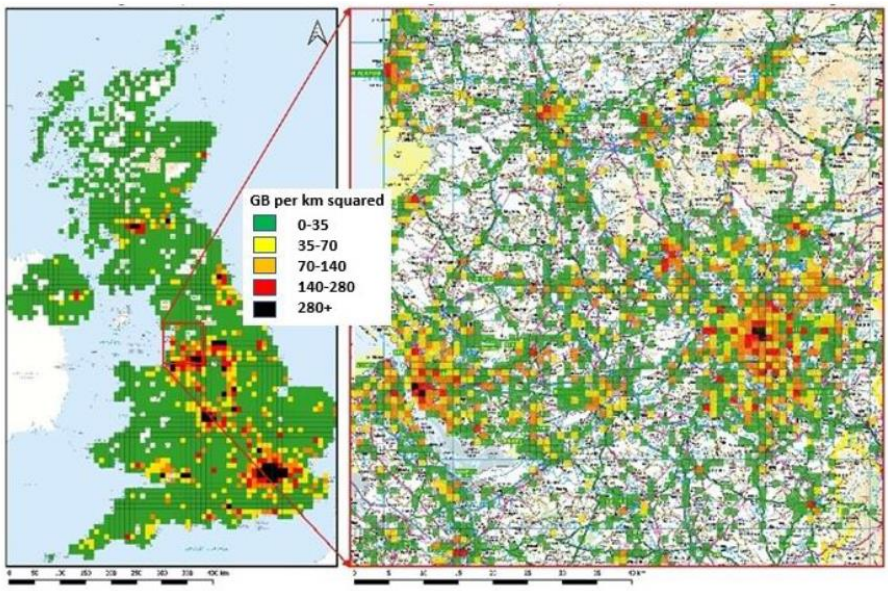
An important consideration with a view to future sharing with MOD is that urban areas exhibit higher data consumption compared to rural areas primarily due to population density rather than a substantial variance in data consumption among rural users, according to Ofcom. This particular point is demonstrated in their report on mobile data demand discussion paper from February 2022[24]presenting a map of the 'hourly' mobile data traffic distribution for the UK. The specific map shown below illustrates

[25] Connected Nations 'England Report 2023', Ofcom, 2023 https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/multi-sector/infrastructure-research/connected-nations-2023/connected-nations-2023-england/ [Accessed 18 June]

[26] Analysys Mason, 2023 https://www.analysysmason.com/research/content/regional-forecasts-/wireless-traffic-forecast-rdnt0/ [Accessed 18 June]

[27] Ericsson Mobility Report 2024 Q2 June 2024, https://www.ericsson.com/en/reports-and-papers/mobility-report/reports/june-2024

how Ofcom has captured and presented such data traffic distribution indicating where across the UK the highest density of mobile data traffic demand is generated. As expected, the highest concentration of the largest volume of demand can be seen in the UK's largest towns and cities. It should be noted that this data will include FWA/hotspot/dongle data use on these networks as well as 'mobile'.



Source: Ofcom

Figure 4: Extract from Ofcom report on total average hourly data traffic for the UK and Liverpool – Manchester corridor

Nevertheless, it is clear that mobile network data traffic growth will continue in the near future and thus interest in accessing suitable mobile spectrum.

Demand for MOD spectrum and access conditions

One particular MNO has indicated strong interest in securing access to the lower 2.3 GHz to complement existing holdings. More information is provided in section 6 (Potential Candidate Bands).

Besides this very specific interest, there is very limited interest in accessing MOD bands at the moment. However, industry stakeholders[28] and vendors[29],[30] note there is a need for additional spectrum for 6G to meet demand for capacity growth without requiring additional cells sites and believe that 7.1-8.4 GHz will be an appropriate band to do this. The argument as to whether or not this behaviour is spectrum-efficient is purely financial. In a sense this use will utilise the 7.1-8.4 GHz more intensively that is used by the MOD, but it avoids a more intensive use of the existing mobile operators spectrum holdings. As for access conditions, mobile operators are really only interested in dedicated spectrum but if the only option is for sharing, then the terms will need to be compelling enough to ensure high levels of certainty to justify investments and manage risk. It has been pointed out that agile and or dynamic sharing may

[28] GSMA, Setting the Stage for 6G, March 2023, https://www.gsma.com/connectivity-for-good/spectrum/setting-the-stage-for-6g/

[29] Nokia, 6G mod-band spectrum technology explained, March 2024, https://www.nokia.com/about-us/newsroom/articles/6g-mid-band-spectrum-technology-explained/

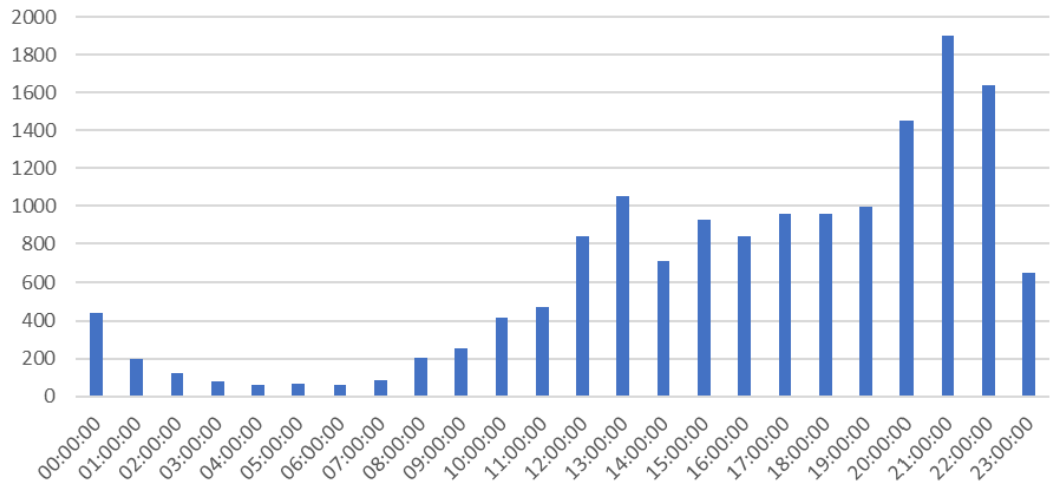
[30] Ericsson, 6G spectrum – enabling the future mobile life beyond 2030 https://www.ericsson.com/49ac9c/assets/local/reports-papers/white-papers/2024/6g-spectrum.pdf

create additional complexities and risks in operational network management with additional overhead to support the required conditions for sharing , so they would prefer that any ‘shared’ bands were given over to their exclusive use, perhaps geographically, for the period of the contract, i.e. shared, but exclusive over a defined time period and not exclusive except when MoD needs it.

The challenge for future sharing lies in how to sufficiently meet the needs of MNOs together with those of the MOD as there is clear misalignment when it comes to their optimally desired use. This means MNOs would need to compromise on the basis of shared access to harmonised mobile bands where the desired geography overlaps with areas of less critical (and low) usage by the MoD, and/or time where there are no (or highly limited) military operations.

The ‘busy-hour’ in telecommunications traditionally identified the peak demand to be satisfied, and which dimensioned the required infrastructure and spectrum needed. In more recent times, data demand away from business hours and the transition to more homeworking has changed when different locations experience their peak demand. The desire to reduce power consumption, also means that operators will selectively turn-off different carriers in some locations at some times. This has changed the characteristics of the ‘busy hour’, and when spectrum is ‘utilised.

During the course of this study, the study team were able to obtain information on the utilisation of MNO networks. This is helpful to inform when capacity is at a peak, and when access to supplementary (even low quality) spectrum could support ‘extra capacity’, without limiting the network ability to support high quality core services. As can be seen from Figure 2, the busiest hour per site varies substantially across this (anonymous) UK network. However, the peak in the late evening does suggest that use of MOD spectrum (whose use is normally in typical office working hours) could be useful to supplement capacity if the areas are sufficiently complimentary. However, specific use details are not available.



Source: Confidential

Figure 5: Overall Busiest Hour per site, irrespective of sector split

4.2 Rural Broadband

Trends and historical context

In the realm of rural broadband, significant advancements are underway with a notable shift towards fibre deployment driven by governmental and regulatory initiatives. According to recent findings from Ofcom[31], the accessibility of full fibre has expanded to encompass 57% of premises in the UK, totalling 17.1 million locations. This represents a marked increase of 15 percentage points, equating to 4.6 million more premises compared to figures from 2022.

As a consequence, wireless internet service providers (WISPs) have been less dependent on the use radio spectrum to supply broadband to some areas of the UK. This provision is mainly in the 5GHz Wi-Fi bands using proprietary linking technologies as well as open standards, although the quality of service can be less than desirable due to the lack of frequency management and coordination. This desire to improve link quality has resulted in pressure for WISPS to access Shared Access spectrum using 5G-like FWA services, and they certainly made up the majority of the initial tranche of users in these bands.

Demand for MOD spectrum and access

There is scope for suitable MoD spectrum to be utilised for these services, although in our discussions we found little appetite for this at present.

The problem is, as always, the potential for outages caused by MoD wishing to use the spectrum at certain times or with little warning and there being no alternative spectrum available to move the service to, although at least 5G-like services can potentially utilise carrier aggregation and the loss of carrier in one band can be mitigated by other carriers in other bands if the WISP is sufficiently networked to offer this. WISP business models are constrained, so this is not always possible.

4.3 Utilities

Trends and historical context

As power generation becomes increasingly less centralised with the introduction of renewable sources such as solar and wind power, the previously static unidirectional flow design of the distribution grid has changed to a much more dynamic multidirectional flow design. This has necessitated significant changes in the way the flow is managed and metered, resulting in a proliferation of sensors and switches not previously required as well as significant investment in upgrading the physical infrastructure to manage considerable new energy being injected into it in places not originally considered.

The spectrum previously used to manage the grid is no-longer sufficient and more spectrum is required to accommodate the significantly higher interaction and refresh rates now needed.

Demand for MOD spectrum and access conditions

Whilst some distribution utilities maintain resilient voice-based radiocommunications networks that can be used for switching and restoration in emergencies, the majority of switching and day-to-day management takes place on a multitude of platforms such as commercial cellular networks for

[31] Connected Nations 'England Report 2023', Ofcom, 2023 https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/multi-sector/infrastructure-research/connected-nations-2023/connected-nations-2023-england/ [Accessed 18 June]

telemetry and telecontrol (M2M), although this is not ideal as the data flow from sensors is upload-heavy as opposed to conventional commercial mobile data, which is download heavy, so commercial mobile networks are not always appropriate for utility use.

In addition, localised short-range device networks (SRD) are used to collect data across, say, a switching field, for on-pass via an M2M gateway.

There is scope for future use of LoRa devices and a more comprehensive LTE/IMT-based low-capacity resilient network, the latter with the correct data profile for upload-heavy applications. The number of RTUs in use would still necessitate offloading the majority of non-critical RTUs to commercial networks to avoid overloading the necessarily low capacity of the resilient network. In the event that access to specific RTUs becomes critical, they could be migrated to the resilient network for the duration of their criticality, such as during a power outage that would take the commercial network off-air or limit its capacity.

The overall resilience of utility telecommunications is achieved by using both fibre and fixed links to maintain path diversity with near instant handover, so the argument that fixed links can be replaced by fibre is, as is usual, not valid as both are required. Again, it should be noted that fibre outages could be localised, such as when contractors dig up a cable duct, or more comprehensive such as a major power outage or natural disaster and utilities need to plan for such contingencies.

To this end, utilities have expressed interested in:

- Gaining access to an additional 1 MHz at 10.5 GHz to improve the efficiency of the current holding
- Additional access to sub-gigahertz spectrum, ideally in the 410-430 MHz range to benefit from international device ecosystem

4.4 Low power / IoT type communications

Trends and historical context

There is an increase of use and deployment of IoT-enabled devices, such as sensors, trackers, and monitoring tools, that will require connectivity. Below are some illustrative examples:

- In agriculture, IoT devices equipped with sensors monitor soil moisture, temperature, humidity, and other crucial parameters, optimizing resource allocation, reducing waste, improving crop yields, and minimizing environmental impact. Wearable IoT devices for livestock management track location, health, and behaviour, enhancing livestock health, productivity, and reducing operational costs;
- In transportation, real-time fleet tracking and management through IoT improve safety and ensure optimal conditions for transporting perishable items. These may also improve safety with remote monitoring of vehicle conditions, driver behaviour analysis, and emergency response systems.

Demand for MOD spectrum and access conditions

In order to meet the growing demand for IoT solutions, there emerging players, and solutions such as satellite IoT Myriota, Kineis, and Sateliot are providing reliable connectivity anywhere through their global satellite networks and solutions.

Myriota, for instance, operates within the 400.15-401 MHz frequency band, which is allocated primarily for mobile satellite and space research, and secondarily for space operations, with potential military use. These niche players leverage low power and duty cycle operations, making them potential sharers for MOD bands.

We have also found evidence of demand from terrestrial IoT players who may seek future access to MoD frequencies. Similar to satellite IoT, the natural profile of these terrestrial IoT solutions may align with the conditions required by military operation.

4.5 PMSE

Trends and historical context

The use of audio and video PMSE is remarkably diverse, ranging from large-scale events like the Eurovision Song Contest and major sports championships to local theatres, trade fairs, and religious venues. This also translates to significant variations in spectrum demand, with high-profile large events requiring considerably more resources due to the sheer number of microphones and other equipment deployed.

Currently, the core frequency range employed for audio PMSE is the frequency range 470-694 MHz. It is available across Europe and beyond (ITU Region 1), This is because it is allocated on a secondary basis (as per footnote 5.296) to land mobile service, intended for PMSE, it has established sharing conditions with regard to DTT, and is well supported by equipment manufacturers.

Evidence[32] suggests that overall spectrum demand for both audio and video PMSE spectrum is on the rise. This is primarily driven by a growing number of PMSE users, in terms of equipment and devices used at a given location or event, and the number of events/locations at which PMSE is required. As events become more innovative and interactive, the use of 4k cameras becomes ubiquitous, drones are used more, viewers demand video feeds that can now be achieved, the bandwidth required increases.

To support this, PMSE's use of 470-694 MHz is being complemented by access to other frequency ranges on a shared basis, such as the lower 400 MHz band,2GHz and 7 GHz frequency range. The operational nature of PMSE, which is typically short-term and confined to specific geographic locations and occasions, makes it compatible with various other spectrum users, including the MOD. For example, the 2 GHz frequency range (2.20 - 2.29 GHz) is extensively used for video PMSE and has become the ‘go-to’ band for pre-coordinated access between MOD and PMSE users.

There are a number of technology developments that can offer potential improvements for PMSE users to use the spectrum more efficiently, such as 5G PMSE, Wireless Multichannel Audio System (WMAS**),** .and/or Cognitive PMSE (C-PMSE). While these technologies are promising, they are not yet commercially proven to meet the sector's high quality of service and low latency requirements.

- **5G for PMSE:** 5G networks could enhance the data links between equipment and control rooms for event organizers and broadcasters, offering greater throughput speeds and higher capacity, especially during major live events, compared to 4G.
- **Wireless Multichannel Audio System (WMAS):** This system uses a single wideband RF channel to deploy multiple audio channels, potentially improving spectral efficiency by up to 50%. However, it is still in the standardization phase and has limited commercial adoption.
- **Cognitive PMSE (C-PMSE):** This technology enhances performance by dynamically sensing interference and channel availability, automatically assigning frequencies to PMSE devices, thus reducing interference.

[32] European Commission, Directorate-General for Communications Networks, Content and Technology, *Study on the use of the sub-700 MHz band (470-694 MHz) – Executive summary*, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2759/041246 [Accessed 17 July 2024]

Demand for MOD spectrum and access conditions

Despite the increasing demand for spectrum at large events for PMSE purposes (both for audio and video assignments) there is a possibility that some spectrum might be lost in future. The outcome of WRC-27[33] (introduction of a secondary mobile allocation in Europe) could potentially reduce the amount of spectrum available for PMSE applications in those countries that opt to introduce mobile networks in that part of the band.

Stakeholders highlighted during the consultation that the necessity for PMSE to access additional frequencies is somewhat tied to future developments in 470-694 MHz. Additionally, they emphasised that widely utilised bands such as 7 GHz range is facing competition from other users (such as those in the Upper 6 GHz range).

Consequently, stakeholder expressed significant interest in 1350 -1400 MHz, identifying it as a potential key candidate for future sharing with MOD in the UK. This is primarily due to the following reasons:

- Propagation characteristics: Any new spectrum would need to be in the sub-1.5 GHz range to ensure that audio devices function effectively, avoiding issues related to signal directivity and body absorption
- ECC Report 245[34] and Amended Recommendation 25-10 provides compatibility studies between wireless microphones and other systems (including military systems) in the frequency range 1350-1400 MHz in Europe

It is not expected that PMSE users will change their way of accessing MoD spectrum, in the short to medium term, as the existing model has proven effective for both MOD and PMSE. However, these principles and model could potentially be extended to other types of spectrum users, provided they have a similar usage profile to PMSE.

[33] ITU, Final Acts WRC-23 Available here: https://www.itu.int/pub/R-ACT-WRC.16-2024 [Accessed 17 July 2024]

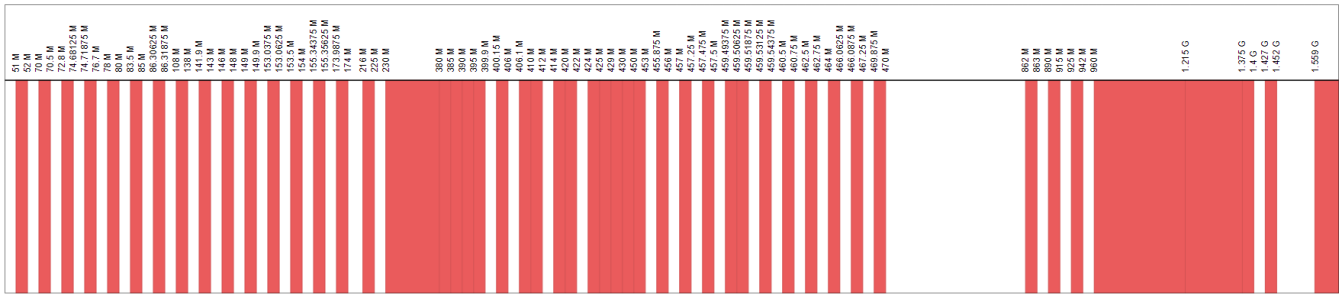
[34] ECC CEPT Report 2016 'Compatibility studies between PMSE and other systems/services in the band 1350-1400 MHz' Available: https://docdb.cept.org/download/1242#page=17&zoom=100,72,166 [Accessed 17 July 2024]

ERC Recommendation 25-10 'Frequency Ranges for the Use of Terrestrial Audio and Video Programme Making and Special Events (PMSE) applications' Amended 2016 Available: https://docdb.cept.org/download/2431#:~:text=This%20Recommendation%20therefore%20pursues%20the,to%20the%20range%20of%20frequencies [Accessed 17 July 2024]

5 Overview of MOD spectrum use

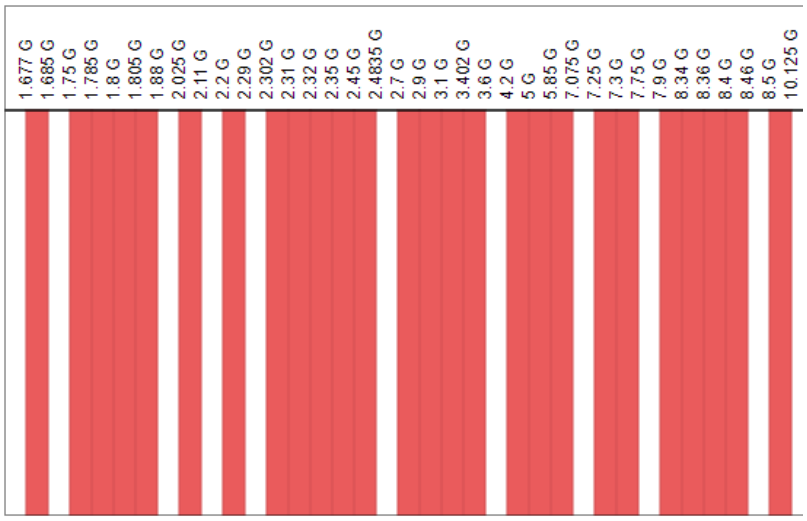
UK MOD is the largest Public Sector spectrum user in the country, with one of the single biggest holdings. Under 10 GHz, approximately 7760GHz is available for military use, mainly at the upper end of that region. Although many of the details of its use are classified, MOD relies heavily on its existing spectrum holdings. The military uses applications across its spectrum from very low frequency to microwave bands in order to support communications (both terrestrial and satellite), situational awareness (Radar, LIDAR, Passive Radar, Signals Intelligence Systems SIGINT), as well as electronic warfare and telemetry and navigation, among other systems. Spectrum access is also needed for training, testing and security at military operations.

At first glance, military peacetime spectrum use, (it is important to recognise that this report addresses peacetime use only), may not appear to be the most efficient. MoD (Public Sector, but this is mainly military) maintains large holdings of spectrum as shown in the plots below.



Source: Ofcom FAT

Figure 6: Military (public Sector) spectrum allocations HF to mid UHF



Source: Ofcom FAT

Figure 7: Military (Public Sector) spectrum usage mid UHF to SHF

Use of this spectrum is often affected by international treaties and accepted NATO use[35], which may not always mean the spectrum would be used in the UK except for testing and limited practice use, but it must be maintained, although this means that actual use is often scheduled, or time and location focused. An example of this would be the UHF Aeronautical Band, which is used in the UK but not all of it as this is an international band and certain frequencies are set aside for specialist use such as space communications. In this case, the UK is keeping those frequencies clear and to do this the frequencies are part of the MoD holding, but not used by MoD. Again, this is similar to the way that the Civil Maritime and Aeronautical bands are managed, so it is not unusual.

More details on the use of MOD in specific bands is provided below. As explained in the above section, this has prompted several spectrum sharing initiatives, some of which have resulted in the reallocation or shared use of spectrum. In the past, efforts have focused on reallocating frequencies from public sector users (primarily UK MOD) to civilian users.

However, with the growing use and demand for military spectrum driven by the modernisation of military systems, including drones and automation, coupled with increasing geopolitical tensions and active conflicts, the UK MOD does not deem it possible to release any more of its frequencies. Nevertheless, it is willing to share more spectrum where feasible, encouraging the most efficient use of spectrum while still protecting and prioritising its national security and mission-critical functions. In fact, UK MOD shares approximately between 80-85 per cent[36] of its current spectrum with both public and civilian users, although not dynamically or in an agile way.

5.1 Spectrum demand

The military case for continued access to the spectrum is related to Defence policy tasks. The UK Integrated Review of Security, Defence, Development and Foreign Policy (IR)[37], published in March 2021, is a comprehensive strategic document outlining the United Kingdom's approach to global challenges and opportunities over the coming decade. The document highlights the UK's strategic commitment to automation and military modernisation as a core component of its defence and security strategy, recognising that significant investments are being made to foster innovations in autonomous systems, space, robotics and AI among other areas.

In parallel with changes and uptake in the civilian use of spectrum, military use has been changing in a similar fashion. Enhanced electronic warfare capability and investment in new technologies outlined in the Review will increase MOD spectrum demand in the medium and long term. In a similar vein, NATO's Science & Technology Trends 2020-2040 report[38] also highlights the challenges to interoperability

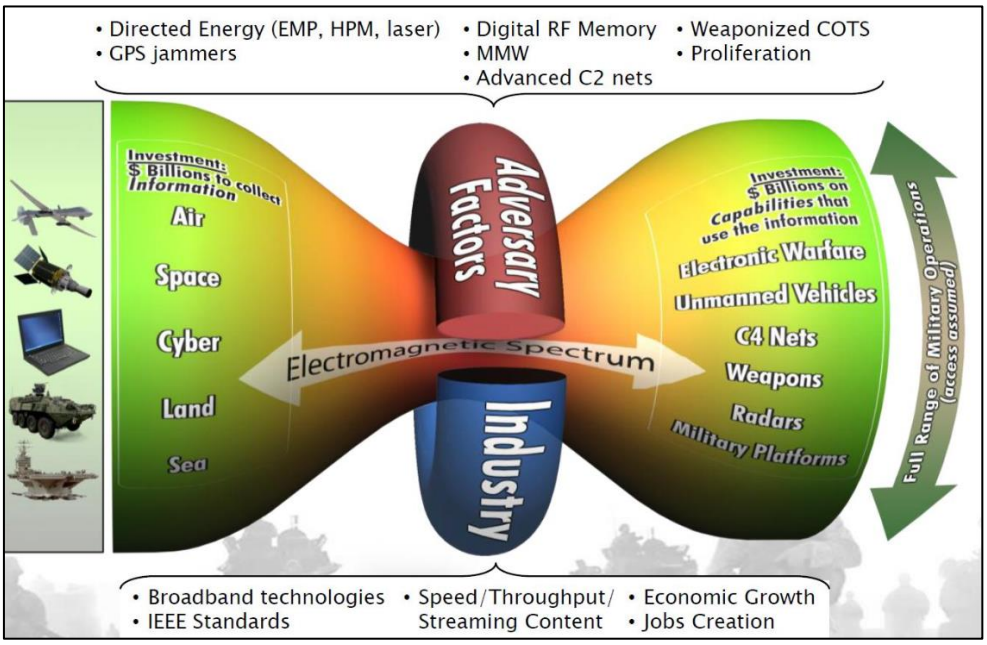
[35]NATO and NATO member nations harmonise spectrum for military use as defined in the NATO Joint Civil/Military Frequency Agreement (NJFA) 2014 https://english.nmhh.hu/document/211426/NATO_Joint_Civil_Military_Frequency_Agreement_NJFA.pdf

[36] Ofcom, 2022 https://www.ofcom.org.uk/siteassets/resources/documents/spectrum/spectrum-information/frequency-allocation-table/fat-civil-military-sharing-arrangements.pdf [Accessed 18 June 2024]

[37] The UK Government, 2021 https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-reviewof-security-defence-development-and-foreign-policy [Accessed 18 June 2024]

[38] NATO Science and Technology Organization, 2020 https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf [Accessed 18 June 2024]

resulting from an increasing number of users fighting for access in an ever more crowded spectrum as shown in the image below.



Source: NATO Science &Technology Organization

Figure 8: High-level overview of factors and drivers of the evolving military spectrum landscape

The evolving landscape of defence spectrum needs, and capabilities has been recognised by DSIT in its Spectrum Statement[39], along with the accompanying documents. This rise is largely driven by several factors, including the proliferation of advanced battlefield networks and the need for higher data rates[40]. The growing utilisation of unmanned aerial vehicles (UAVs) has also contributed to this trend, as they operate in a network that often includes ground control station, air traffic control systems, satellite systems as well as other Unmanned Systems such as Unmanned Surface Ships (MASS). These technologies require substantial bandwidth to function effectively, further intensifying the demand for military spectrum. As these innovations continue to evolve, the pressure on available spectrum resources is also expected to increase.

During our discussions with the MOD, an illustrative topic was the significant role of drones in the ongoing Ukraine conflict. Drones have introduced new capabilities, such as video surveillance and direct attacks. The extensive use of these drones has specifically placed significant pressure on the MOD's spectrum below 5 GHz.

[39] The UK Government, 2023 https://www.gov.uk/government/publications/spectrum-statement/spectrum-statement#public-sector-spectrum-use-1 [Accessed 18 June 2024]

[40] UK MOD, 2019 https://assets.publishing.service.gov.uk/media/5d84d4eaed915d5241461dc6/Electromagnetic_Spectrum_Blueprint_V1-O.pdf [Accessed 18 June 2024]

5.2 Spectrum sharing

While all actors involved (MOD, DSIT, Ofcom and private industry) are all interested in spectrum sharing – as it is seen as a way of extending access for more users – the technologies, applications, policies and approaches are still emerging and may face challenges.

Introducing new users into spectrum bands presents a series of challenges, including potential interference, prioritisation of use etc. This complexity is further heightened when the incumbent users are military applications. Military systems often possess a mix of either advanced receiver capabilities, but also older equipment more prone to interference and the nature of military operations can prevent the disclosure of critical information about their use. Lifecycle of civilian and military equipment is often different, with military equipment often undergoing significantly longer operational lifecycles compared to their civilian counterparts.

Thus, both technical and non-technical issues must be navigated carefully to ensure that new users can be integrated without compromising existing military functions.

Below is a table highlighting some of the unique characteristics and requirements of the MOD, which make spectrum sharing more complex in comparison to private users. These are some of the considerations to keep in mind for future sharing.

Table 3: Key issues and requirements for implementing future defence sharing arrangements

Key issue	Considerations
Predictability	It is extremely difficult to predict the military demand on spectrum and ensure its capabilities have the agility and flexibility to operate in different parts of the spectrum. This consideration may make spectrum unappealing for private commercial users, as the uncertainty makes it challenging to develop a commercial case for investment and deployment.
'Train as you fight' capability	Numerous military operations use the spectrum, including command and control (C2), signature management, and navigation warfare. The 'train as you fight' requirements emphasises conducting such operations under conditions that closely resemble combat situations. In doing so, UK MOD often take part in joint exercises with NATO allies and other international partners. These exercises intensify the use of spectrum, particularly in NATO harmonised bands.
Obfuscation	Obfuscation of spectrum use, and operations is essential for protecting military capabilities, maintaining operational security, and ensuring the effectiveness of military communications and electronic warfare activities. Ofcom already releases information on boundaries around some sensitive MoD/GCHQ locations where shared spectrum use is precluded. More intense sharing could be permitted if more granular information[41] is known about use – though there are limits on what level of disclosure is acceptable or desirable, which includes location, making exclusion zones necessarily vague. Similarly, industry stakeholders has expressed concerns[42] over the difficulty of implementing new and more sophisticated sharing methods without having access to detailed information about military usage.

[41] Ofcom, 2023 'Opportunities for dynamic or adaptive approaches to managing spectrum in the UK' [Accessed 01 June 2024]

[42] PolicyTracker, 2024 'IMT to be studied by ITU threaten NATO use' [Accessed 01 June 2024]

Pre-emptive capability	MoD needs the ability to gain back spectrum whenever required, and most likely at short notice without compensation, because otherwise the nation's economic and national security will be exposed to undue and significant risk. In exceptional circumstances, Crown access to spectrum would preclude any requirement to apply for a licence, but it may also be beneficial if a mechanism was implemented to terminate 3rd party use of specific Crown spectrum at short notice (even though their use had previously been agreed) . This implies that 3rd party use of Crown spectrum requires some kind of automated frequency agility or management as the requirement for spectrum may be immediate. This requirement is not new as automated frequency control to avoid causing potential interference was the main reason for mandating MPT1327 trunked radio systems when Land Mobile was introduced into a broadcast band (Band III) in the early 1990s.

5.3 Bi-directional sharing

There is growing consensus[43] among military stakeholders that 5G and other standardised technologies may enable a wide range of military applications, such as autonomous vehicles, command and control systems but also logistics, smart military bases and other use cases.

UK MOD is currently assessing its options for leveraging 5G technologies to benefit from the extended capabilities over 4G and extensive ecosystem of device types (beyond normal smartphones). One potential scenario discussed for this study involves smart bases, which will incorporate private 5G and other technologies like fibre, to support facial recognition systems, high-definition cameras, etc.

Another scenario includes MOD developing its own "small or fill-in" networks, functioning practically as a Mobile Virtual Network Operator (MVNO) and using network slicing and roaming between an MOD network and civilian network. It is still in the early stages, but it is anticipated that the final solution will likely be a hybrid approach, incorporating multiple strategies.

To enable this, UK MOD is keen to explore various approaches, including accessing civilian frequencies (primarily MNOs) in those locations or instances where they are not being used by the mobile operators. A starting point in the discussions could be enabling military shared access to the 2.6 GHz band. This may be feasible due to the current usage patterns of the band. The MOD will primarily aim to use this spectrum at barracks and in remote or rural locations where it seems to be currently underutilised.

Under the LAL scheme, the Ministry has some existing arrangement to share MNO frequencies at fixed locations where there is no or little scope for mobile deployment. However, in our discussions, both civilian and military stakeholders have highlighted flaws in the current approach. More information on these barriers is provided in Section 7. Therefore, a potential sharing defence/civilian sharing framework may also need to include a consideration to support such sharing. This means that any mechanism for future shared spectrum use, including transfer between public and private sectors needs to consider the licensing arrangements that are required.

[43] Please see Rand Corporation, 2023 'Opportunities and Risks of 5G Military Use in Europe' and NCI Agency, 2020 'Potential of 5G technologies for military application' [Accessed 17 June 2024]

6 Potential candidate bands

As explained above, the MOD has the largest spectrum holdings of any public body across a wide range of frequencies. Consequently, we have concentrated our efforts on identifying and assessing the feasibility of sharing a specific set of bands. The rationale for selecting these bands includes one or more of the following reasons:

- Bands previously identified by the PSSRP but never access never materialised
- Bands in which civilian users have expressed interest but access has not been achieved
- Bands currently under discussion in the international community (i.e.WRC-27 IMT bands)
- Bands that the MOD has expressed a willingness to share

Based on the foregoing, an initial set of bands have been identified as being candidates for shared use of MOD spectrum:

- Lower 2.3 GHz: it has been identified in 2016 as a high priority band under PSSR programme but civilian usage has not yet materialised. There is interest from an MNO to complement its existing holdings in the upper 2.3 GHz
- 400.15-401 MHz frequency band: this band is allocated (on a primary basis) to mobile satellite and space research and on a secondary basis to space operations. Mobile satellite use identified in the UKFAT under FN2.1[44]. There is interest from IoT satellite operator.
- IMT in the bands 4400-4800 MHz and 7125-8400 MHz, due to be addressed at WRC27, under Agenda Item 1.7. There is also potential interest from other innovative users, such as Agritech applications.
- NATO harmonised 1350-1400MHz band in which European compatibility studies took place in 2016 to allow PMSE use,

A brief technical consideration of these three applications will be developed in below sections after the likely constraints of MOD use is considered.

During the course of the consultation phase of this study, technical details of the systems that would operate in the shared bands were sought. Sensitivity about the exact nature of use (technical characteristics, application, time and location of use) precluded sharing of these details with the study team. It is noted that in discussions with Ofcom[45], it was noted that 'technical studies need to look at the timing, nature and technical details of MOD systems that would need to be protected in any band' and that 'assessment of what sharing is possible is based on the technical criteria and technical protection requirements of what are needed for each systems – along with where and when it is used'.

Coupled with a lack of any compelling evidence of demand for increased shared access to public sector spectrum, means that the opportunities to assess sharing scenarios in any detail are limited.

To inform this study, it is useful to examine the systems and the restrictions that were identified by Ofcom, after technical analysis by the MOD in the Information Memorandum for the award of 2.3 and 3.4 GHz spectrum as part of the PSSR programme[46], and the sharing constraints that the MOD have

[44] UK FAT Footnote 2.1: "Responsibility for granting permissions to use frequencies in this Allocation rests with Defence. All frequency permissions are reserved exclusively for Defence use except where assignments for Civil use are agreed with Ofcom.".

[45] Ofcom, confidential *pers. comm.*

[46] Ofcom, Information Memorandum. "The award of 2.3 and 3.4 GHz spectrum bands", 11th July 2017. https://www.ofcom.org.uk/siteassets/resources/documents/consultations/uncategorised/7904-2.3-3.4-ghz-auction-design/associated-documents/secondary-documents/info-memorandum.pdf.

previously made public[47] in a presentation to the SPF. In addition, it is helpful to consider Ofcom's discussion paper on dynamic and adaptive approaches to managing spectrum[48], and consultation on evolution of the shared access framework[49]. These are discussed below.

6.1 Lower 2.3

Constraints identified in the 2017 Information Memorandum ("2017 IM")

As part of the PSSR, the MOD released spectrum in the 2.3 and 3.4 GHz bands to Ofcom, so that they could award the spectrum to non-public sector users. The 2017 IM is a key document ensuring that any auction bidders for the 2.3 and 3.4 GHz bands knew what it was that they were bidding for – including the constraints on use from any MOD in neighbouring bands. Ofcom informed potential bidders that Crown use of any band can occur: "Interference may stem from Crown use of the bands themselves and/or from Crown use of adjacent bands. We believe this is likely to be occasional in nature – if it arises at all – but Ofcom can offer no guarantees that this is the case".

Ofcom invests a lot of effort in preparing auction awards – including development of an Information Memorandum. Despite this, Ofcom, citing national security considerations, note that "It is possible that interference may arise from these situations in ways we do not currently anticipate, or from other situations which are not yet foreseen or about which the MOD has not informed us". This caution was motivated primarily by MOD use in adjacent bands. Clearly any users of shared MOD spectrum would struggle to operate high availability (all the time, everywhere) services, unless alternative 'clean' spectrum is also available for use. Shared use is more likely to be suited for users who can work around the time and location of MOD use, and/or use access to MOD spectrum as a useful 'additional' band to improve service at times when it can be made available. PMSE has been a regular user of MOD spectrum where spectrum access for the duration of a localised event (e.g. Open Golf Tournament, Grand Prix racing, Glastonbury) can be work around MOD planned use.

According to the 2017 IM, use of bands adjacent to the 2.3 GHz band is limited. For example:

- EMC testing is performed approximately 25 times per year for 2-3 days at a time (spread across 3 locations), where "All transmissions occur in an infrequent manner and are only likely to have an intermittent localised affect at most".
- Other Land-based systems tend to have low height and power, though some higher transmissions (up to 42dBm EIRP do occur). It was concluded that "There remains a limited risk of interference to a base station within a few hundred metres of these sites."
- Emergency services are planning on using LTE equipment to support Air-Ground and Gateway (small cells proximate to Emergency Services vehicles) Communications. These gateways would only operate when the vehicles are stationary. Clearly, the interference potential is likely to be localised and limited to the duration of the emergency.
- Airborne systems are noted to operate in localised areas (test ranges) and UK wide. Localised sites are "unlikely to cause any degradation to any LTE base stations with additional filtering below 2340 MHz". Though it is noted: "Care should be taken when locating base stations close to MOD

[47] SCDD, "Defence-Controlled, Dynamic Spectrum Access". Presentation to UK SPF. 17th Nov 2020.

[48] Opportunities for dynamic or adaptive approaches to managing spectrum in the UK. Ofcom Discussion Paper (and associated Annexes). https://www.ofcom.org.uk/spectrum/innovative-use-of-spectrum/flexible-and-adaptive-spectrum.

[49] Evolution of the shared access licence framework. Ofcom consultation. Call for inputs published 28th March 2023. Statement Pending.

used airfields to avoid Award of the 2.3 and 3.4 GHz spectrum bands – Information Memorandum 34
interference from these systems below 1000 feet – during take-off and landing. Currently these
flights occur at Warton, although very occasional use is possible at other airfields". Telemetry is
used to support UK-wide flights – typically above 5000 feet, with a speed of 600 knots, and can occur
whenever the aircraft are operating (typically 8 hours a day, 5 days per week). It is considered that "a
few dB desensitisation may be experienced for a few 10s of seconds as an aircraft flies overhead,
although this will depend on the base station antenna pattern in the vertical direction."

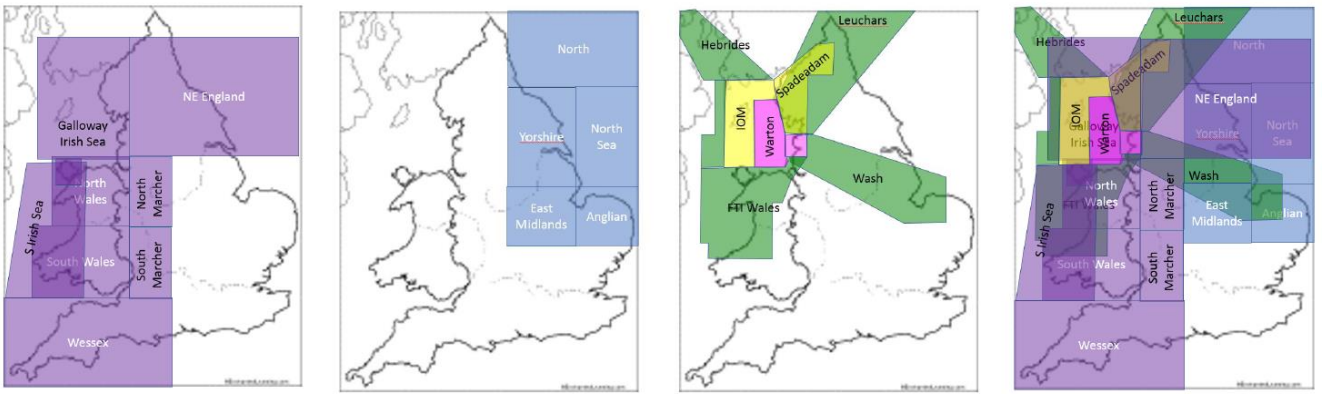
Related to the 3.4GHz band:

- MOD operate co-channel radar typically pointing out to sea from the West Coast of Scotland (Applecross) or from Portland. These systems operate across the 3.4GHz band on 2 occasions per year. MOD will avoid transmitting in the direction of IMT base stations to protect their systems from interference.
- EMC testing is performed approximately 25 times per year for 2-3 days at a time (spread across 2 locations). Transmissions will not be co-channel and "all transmissions occur in an infrequent manner and are only likely to have an intermittent localised effect".
- MOD operate a number of radar systems and other airborne systems below 3410MHz. It is noted that the MOD operations typically seek to reduce interference (e.g. "Any shipborne system operating above 3100 MHz is not permitted to radiate within 5km of the UK coastline"). It is noted that "a helicopter-borne system at 100m altitude in very close proximity to a base station may cause a noise rise of 2 to 3dB".

It is clear that the constraints identified in the 2017 IM, suggest that MOD operation in the bands adjacent to the 2.3 and 3.4 GHz are limited in terms of the geographic area used, or the time duration of use. Wide area uses (e.g. UK wide aircraft operation) will tend to impact other users for a limited period of time.

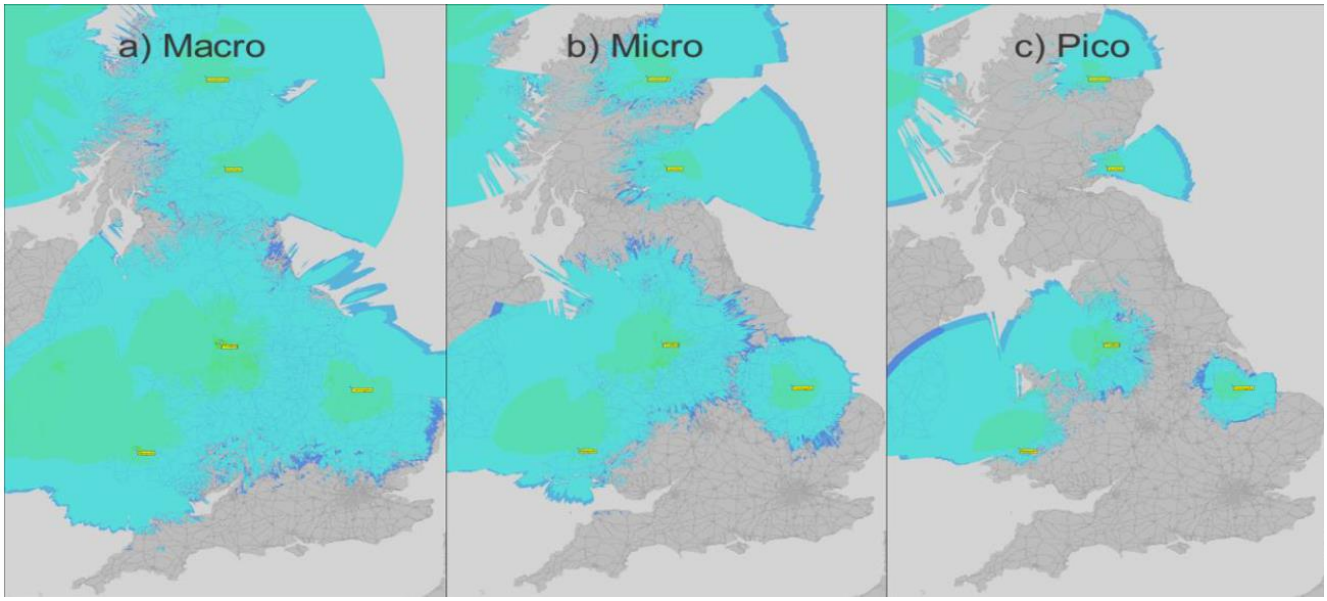
Other identified constraints

It is helpful to review some of the diagrams that were presented to SPF by the MOD as part of the 2020 SPF Presentation which explored spectrum sharing. Figure 6 below shows examples of operational areas used for different airborne systems. Whilst these areas are extensive and could suggest sterilisation for shared use of a large area, the discussion above highlights how practical use is limited to short periods or is in other ways limited in extent.



Source Strategic Command, Defence, Digital presentation to SPF

Figure 9: Examples of airborne systems in operational areas in 2.3 GHz



Source Strategic Command, Defence, Digital presentation to SPF

Figure 10: Example of different coordination areas for different LTE base station types

Figure 7 shows different co-ordination areas that would require assessment to establish the impact of LTE use on potential victim MOD systems. It is not known what assumptions were made of the potential victim characteristics (including antenna orientation), frequency of operation of the assumed propagation assumptions (including topography, clutter, etc). However, it is not unusual for worst case Minimum Coupling Loss assumptions to result in identifying large potential co-ordination zones. This is often a starting point for any analysis in shared use. In practice, detailed assessment of the interference potential (including statistical effects) typically reduces the area where different systems are unable to co-exist with an acceptable level of interference. Efficient spectrum use requires that these detailed assessments are made to improve the uses of any shared spectrum.

6.2 400.15 – 401 MHz band

Myriota is a satellite-based IoT company that uses a constellation of LEO micro-satellites to relay small (20 byte) messages (Earth-space). Network device control data (time, scheduling, satellite orbit parameters) is transmitted in the 400.15-401 MHz band (space-Earth).

This band is allocated (on a primary basis) to mobile satellite and space research and on a secondary basis to space operations and operate under constraints to protect radio astronomy in 406.1-410 MHz with an associated power flux density limit (Annex 1 of Appendix 5).

The Myriota system operates in a number of countries around the Earth, subject to RR Article 5. Within the UK, mobile satellite use in this band is identified for use in the UKFAT under footnote 2.1[50] and footnote 1.3[51].

[50] UK FAT Footnote 2.1: "Responsibility for granting permissions to use frequencies in this Allocation rests with Defence. All frequency permissions are reserved exclusively for Defence use except where assignments for Civil use are agreed with Ofcom.".

[51] Responsibility for assigning frequencies to this Allocation rests with Ofcom for UK Space Agency use. Frequencies in this Allocation are exclusively assigned for civilian use except where permissions for military use are

There would appear to be no technical barrier why Myriota cannot use this (receive) band within the UK, so long as its system can cope with the potential interference by MOD from time to time. However, when approaching UK authorities (both UK MOD and Ofcom), Myriota have not received clear guidance of the situation for deploying its terminals and cannot find an obvious reason to not operate its network in the band. This is a procedural issue that requires resolving between Ofcom and MOD.

6.3 IMT use in 4GHz and 7-8 GHz bands

As noted above, WRC27 has an agenda item, AI 1.7 to explore the potential for adopting 4400-4800 MHz and 7125-8400 MHz for use of IMT. Currently, within the UK, the UK allocations for these bands are as shown in Table 3.

Table 4: Frequency Allocation in the UK and RR Region 1 subject to study in WRC-27

Band (MHz)		UK Footnotes	RR Footnote
4400 – 4500	FIXED MOBILE	UK2.1 UK2.1	 5.440A
4500 – 4800	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE	UK2.1 UK2.1, 5.441 UK2.1	 5.441 5.440A
7075 – 7145	FIXED MOBILE	UK1.1, UK2.1.2, 5.458 UK 1.1, 5.458	5.458, 5.459 5.458, 5.459
7145 – 7190	FIXED MOBILE SPACE RESEARCH (deep space) (Earth-to-space)	UK 1.1, 5.458 UK 1.1, 5.458 UK 1.3, 5.458	5.458, 5.459 5.458, 5.459 5.458, 5.459
7190 – 7235	EARTH EXPLORATION SATELLITE (Earth-to-space) FIXED MOBILE SPACE RESEARCH (Earth-to-space)	UK 1.3,5.458, 5.460A, 5.460B UK 1.1, 5.458 UK 1.1, 5.458 UK 1.3, 5.458, 5.460	5.458, 5.459, 5.460A, 5.460B 5.458, 5.459 5.458, 5.459 5.458, 5.459, 5.460
7235 – 7250	FIXED MOBILE EARTH EXPLORATION SATELLITE (Earth-to-space)	UK1.1, 5.458 UK1.1, 5.458 UK1.3, 5.458, 5.460A	5.458 5.458 5.458, 5.460A
7250 – 7300	FIXED-SATELLITE (space to Earth) MOBILE-SATELLITE (space to Earth)	UK2.1, 5.461 UK2.1, 5.461	5.461 5.461

agreed with the Ministry of Defence. Further information can be found in the document “Space science and meteorology spectrum allocations in the UK”.

7300 – 7375	FIXED FIXED-SATELLITE (space to Earth) MOBILE except aeronautical mobile	UK1.1, 5.461 UK2.1, 5.461 UK1.1, 5.461	5.461 5.461 5.461
7375 – 7450	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile MARITIME MOBILE-SATELLITE (space-to-Earth)	UK1.1 UK2.1 UK1.1 UK1.3, 5.461AA, 5.461AB	 5.461AA, 5.461AB
7450 – 7550	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile MARITIME MOBILE-SATELLITE (space-to-Earth)	UK1.1, 5.461A UK2.1, 5.461A UK1.1, 5.461A UK1.7, 5.461A, 5.461AA, 5.461AB	5.461A 5.461A 5.461A 5.461A, 5.461AA, 5.461AB
7550 – 7750	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile MARITIME MOBILE-SATELLITE (space-to-Earth)	UK1.1 UK2.1 UK1.1 UK1.7, 5.461AA, 5.461AB	 5.461AA, 5.461AB
7750 - 7900	FIXED METEOROLOGICAL-SATELLITE (space to Earth) MOBILE except aeronautical mobile	UK1.1 UK1.6, 5.461B UK1.1	 5.461B
7900 – 7975	FIXED FIXED-SATELLITE (Earth to space). LAND MOBILE MOBILE-SATELLITE (Earth to space)	UK2.1, 5.461 UK2.1, 5.461 UK2.1, 5.461 UK2.1, 5.461	5.461 5.461 5.461 5.461
7975 – 8025	FIXED-SATELLITE (Earth to space) MOBILE-SATELLITE (Earth to space)	UK2.1, 5.461 UK2.1, 5.461	5.461 5.461
8025 – 8175	EARTH EXPLORATION-SATELLITE (space to Earth) FIXED FIXED-SATELLITE (Earth to space) MOBILE MOBILE-SATELLITE (Earth to space)	UK1.3, 5.462A UK2.1, 5.462A UK2.1, 5.462A UK2.1, 5.462A, 5.463 UK2.1, 5.462A	5.462A 5.462A 5.462A 5.462A, 5.463 5.462A

8175 – 8215	FIXED	UK2.1, 5.462A	5.462A
	FIXED-SATELLITE (Earth to space)	UK2.1, 5.462A	5.462A
	METEOROLOGICAL-SATELLITE (Earth to space)	UK1.6, 5.462A	5.462A
	MOBILE SATELLITE (Earth to space)	UK2.1, 5.462A	(NOT ALLOCATED)
	MOBILE	UK2.1, 5.462A, 5.463	5.462A, 5.463
8215 – 8400	EARTH EXPLORATION-SATELLITE (space-to-Earth)	UK1.3, 5.462A	5.462A
	FIXED	UK2.1, 5.462A	5.462A
	FIXED-SATELLITE (Earth to space)	UK2.1, 5.462A	5.462A
	MOBILE	UK2.1, 5.462A, 5.463	5.462A, 5.463
	MOBILE SATELLITE (Earth to space)	UK2.1, 5.462A	(NOT ALLOCATED)

Specific constraints are not possible to evaluate with the information provided. However, from knowledge of typical generic sharing and coexistence arrangements, we can expect the following constraints for the different uses of the MOD services:

- EARTH EXPLORATION SATELLITE (E-s and s-E): EESS is a civil application that shares access to some MOD bands and is used in some adjacent bands to MOD use. Typically, EESS is located in spectrum that relates to the nature of the phenomenon to be studied (little frequency selection autonomy) and tend to be highly sensitive. Co-existence with EESS is highly specific to the phenomenon and the sensors in use. In general, however, EESS sensitivity can constrain use in both co-channel and out of band emissions. The impact and mitigations are highly specific to the uses.
- FIXED: Sharing with FIXED services will be difficult along narrow corridors aligned in the direction of the fixed links (when used by the MOD). These corridors can constrain operation along many 10's or several 100's km. Directional applications, not aligned in the direction of the links can be used. The impact of any constraints will depend upon the FS deployment.
- FIXED-SATELLITE (E-s): Sharing and co-ordination of FSS is made easier if directional transmitters are deployed and planned. FSS off-axis power flux density masks limit the radiation to 'other satellites', than the one intended. A relatively small number of medium-high power transmitters aimed at area coverage (e.g. mobile handsets of base stations) can desensitise FSS satellite receivers. Since they can have wide area beams, interference can be aggregated over a large area. NGSO systems have related concerns, but more care needs to be taken to protect other systems over the range of pointing angles needed to track the satellite constellation – and any GSO systems.
- FIXED-SATELLITE (s-E): Typically, Fixed Earth stations are directional, but sensitivity to interference can constrain use of other transmitters within a region close to any given FSS receiver. Transmissions to NGSO can limit interference to other systems by having a high minimum operational elevation angle.
- MARITIME MOBILE-SATELLITE (E-s and s-E): Similar to the FSS cases discussed. If the use is maritime, then it is likely that distances can reduce the impact on potential victim systems.
- MOBILE except aeronautical mobile: Shared use of spectrum designated for MOBILE is likely to be possible with other mobile services remote from areas of MOD use. Where the spectrum is shared with an uplink satellite (E-s) use, any alternative use will typically need to be (very) low power or indoor.
- MOBILE: As MOBILE except aeronautical mobile. In addition, aeronautical use is permitted. Increased altitude means that the areas that are constrained by operations are increased. The

opportunity to use highly directive antennas is reduced and this again increases the constraints on other systems.

- MOBILE-SATELLITE (E-s and s-E): This has all the considerations of the FSS service. In addition, mobility complicates the co-ordination of the earth-terminal. In general, the directivity of the terminal is less and is therefore more complicated to co-ordinate with other services.
- SPACE RESEARCH (Earth-to-space): These systems tend to transmit relatively high power using highly directional antennas. Reception in this transmit band in the region of these antennas may be constrained.

Subject to WRC27, the IMT community seek to have some of the spectrum in Table 3 identified as an IMT band. Individual countries will decide on the sharing and licence conditions that should apply for any civilian IMT use – in particular if any use is to be shared or assigned on an exclusive basis for MNO use. Any non-exclusive use in these bands would depend upon the specific nature of current and future use - though it is likely that the constraints that would apply in the areas where the MOD are active could restrict the location, time and power that can be used. Lack of any detailed information on the existing or potential uses, prevents any more specific finding at this stage.

At the end of WRC-23, the Conference Preparatory Meeting announced that the technical and operational characteristics needed for sharing and compatibility studies would be available by the end of 2024, although these could be extended to July 2025 if necessary. The sharing and compatibility studies may include terrestrial-to-terrestrial, and terrestrial-to-space coexistence scenarios between IMT system and incumbent services, e.g. fixed service, satellite service, science service etc.

These studies will start to yield more understanding of the sharing potential in the proposed bands.

6.4 PMSE use in 1350-1400 MHz

As noted earlier in section 4.5, the 1350-1400 MHz range is a key target for future PMSE in the UK. It is a NATO harmonised band widely used for aeronautical, land and maritime system, as well as military radars. Within the UK, the band is allocated as follows:

- 1350-1375 MHz
  - Fixed (primary)
  - Mobile except aeronautical (primary)
  - Radio location (secondary) UK footnote 2.1
- 1375 – 1400 MHz
  - Fixed (primary)UK footnote 2.1
  - Mobile except aeronautical (primary)UK footnote 2.1

This band has been studied for the compatibility of audio PMSE usage with a number of primary services under ECC Report 245 which concludes that at least 25 MHz could be made available for audio PMSE. According to the findings, co-channel sharing between the Radiolocation Service/Fixed Service and wireless microphones at the same geographical location would be problematic because of the disruptive effect on the wireless microphone receivers from the radiolocation or the Fixed Service signals.

Therefore, it suggests that by implementing a scanning procedure to identify the parts of spectrum, which are in use by other transmitter(s) and the parts, which are available for successful audio PMSE operation, audio PMSE will avoid being interfered with by Radiolocation/Fixed Service systems and avoid interfering with the Radiolocation / Fixed Service systems.

Geographical sharing for co-channel operation based on exclusion zones around the radars is practical. Cochannel sharing between the fixed service - coordinated and wireless microphones is feasible with the separation distances given in the ECC report’s table.

7 Considerations and barriers for a new framework

This section outlines the key considerations that will inform the development of a new framework for defence spectrum sharing. These considerations mostly encompass technical, procedural, and legal / regulatory aspects, along with existing barriers that the framework will need to address. These have been compiled following the consultations with a diverse group of stakeholders, as detailed in Section 4.

7.1 Considerations of a suitable sharing framework

Any framework should be cognisant of the following:

- It must ensure the appropriate sharing conditions (technical, procedural, and legal) can be met
- Ofcom has an existing legal responsibility to monitor, manage and provide access to spectrum to civilian users (citizen consumers). It should be aware of the current and future demand and utilisation of spectrum.
- The current unmet demand for spectrum access is not clear. The mechanisms for accessing spectrum are not always simple or transparent. Ofcom should monitor and be able to identify cases where access to spectrum has not been able to be satisfied. Ofcom has existing mechanisms (see spectrum sharing framework) in place to provide access to subsets of spectrum for subsets of users (e.g. LAL and SAL). Any framework which allows access to MOD spectrum is likely to be ancillary to the existing Ofcom mechanisms, dependent on the demand and access constraints that a user can accept.
- Ofcom are at the forefront of developing automatic / structured methods of providing database / automated solutions to access spectrum. This is an evolving need. It would make sense that the UK consolidate / harmonise any spectrum access mechanism, that it is future-proof and consistent with the emerging methods and any equipment standards.
- It must be appropriate, proportionate and consider technical and financial implications to MOD implementation.
- MOD's constraints on the conditions of spectrum use (see section 4.2) are to be observed.
- Whilst being helpful in facilitating access to MOD spectrum, the MOD is unable to be candid with their spectrum use to all potential spectrum users – Ofcom has designated personnel who have expertise, knowledge, and privileged insight into MOD spectrum use. Ofcom can be a useful intermediary. The existing processes by which users access civilian and MOD spectrum seem able to be improved. Prospective users are unlikely to care if the spectrum to which they seek access is being provided by the MOD.
- Ofcom could extend the remit of its existing SAL mechanism to support sharing of MOD spectrum. In particular, different mechanisms for accessing different sub-sets of spectrum are unlikely to be relevant.
- It must allow MOD and prospective shared users to have predetermined and agreed-upon conditions to streamline the process, which should be managed through Ofcom. This must account for service interruption (to civil users) in a specific area and timeframe according to MOD needs, notice period among other details
- The MOD can accommodate access to shared spectrum with a low probability of interference in specific areas for planned (short) periods of time. This is well suited to PMSE and other spectrum users who have access to spectrum such as Amateur Radio. These existing sharing arrangements (managed by Ofcom) do appear to work effectively.
- We acknowledge the existing sharing arrangements between MOD and Ofcom are outside the scope of the study as-per the Terms of Reference.

- From time to time Ofcom permits non-standard assignments (typically for events with international interest, or security requirements). The nature of these essential events requires some flexibility in how Ofcom handles some requests for spectrum.
- Any spectrum sharing framework should impose an appropriate overhead – ideally as little of an administrative / technological overhead as possible. A sophisticated near real-time database coordinated system may allow more efficient spectrum utilisation than 'pen and paper' method – but may impose unnecessary overhead in the sharing administration or in the equipment capability. In this study we have not identified any significant additional demand for access to MOD controlled spectrum. However, it is noted that WRC27 may increase pressure for additional sharing – possibly in spectrum for which harmonised equipment standards may be developed.
- In shared bands which are internationally harmonised, there are likely to be benefits in having a sharing mechanism that can leverage any benefits of harmonised use (for both a sharing/management method and of an equipment ecosystem). It is likely that any sharing mechanism should be sufficiently flexible to evolve as more sophisticated sharing methods become standardised.
- Harmonisation provides benefit to MOD users too (in terms of using civil technology, and in terms of being able to re-use existing equipment in other countries during peacetime).
- It must align with the current legal framework or justify changes to the legal framework. One of the topics that came up during the discussions with stakeholders was the potential for a dual-structure regulatory approach in the UK, similar to the US system[52]. We believe that the US model of a separate public sector spectrum entity like the NTIA is not worth considering further for the UK and spectrum sharing model for MOD. This is because, in the UK, we have an entirely different governance model in relation to spectrum management for the public sector. It would require intensive and extensive collaboration and alignment between all government departments (we assume a similar entity would need to cover all public sector spectrum), it would also likely need major legislative updates which could take several years to pass through government.

7.2 Barriers with sharing arrangements identified in this study

7.2.1 Barriers for sharing in MOD bands

The types of barriers that have been identified from discussions regarding use of the different proposed candidate bands, and are centred around the following key areas:

- Efficacy of the information on MOD spectrum use (by both MOD and Ofcom), in order to facilitate access to civilian users.
- Civil users to be able to operate within the constraints imposed on use of Crown spectrum
- Clarity on existing spectrum access arrangements.

Planning access to Crown spectrum must have the required technical information about MOD spectrum usage for each of the bands of interest. It is not required that the spectrum user has such detailed information, as long as they can operate within the constraints of use that are set. Ofcom are in a good position to handle the data and perform this management function.

Currently, there is an established sharing mechanism where PMSE accesses Crown Spectrum, managed by Ofcom. This has particular use characteristics that facilitate sharing Crown spectrum (planned short term, geographically limited, and often pre-coordinated reuse of legacy spectrum use plans). Other users with different use requirements (e.g. long term secure access to spectrum, or wider area coverage) may be more difficult to accommodate within the existing PMSE licensing process and so may require a

[52] See https://www.fcc.gov/engineering-technology/policy-and-rules-division/general/radio-spectrum-allocation

separate process for spectrum sharing, thus creating fragmentation within the overall sharing framework development.

The barriers start to become a problem when the civil users' requirements for sharing are more stringent based on the needs of their customers. For example, the MNOs would ideally access the spectrum using as much transmit power as possible from as many locations as possible for as long as possible similar to how their current licences permit. As soon as there are restrictions across any of those dimensions the interest in sharing by MNOs diminishes.

The appropriate technical conditions would need to be applied in the licences so that users do not cause interference to MOD when they wish to access the spectrum. In addition, the licences would need to include clauses that would ensure that MOD can transmit whenever and wherever they like, noting that this would need to be reasonable to the extent possible, so as not to disrupt the civil users too greatly.

7.2.2 Barriers for MOD using civil bands

The main barrier with MOD using civil bands is the many different relationships the MOD spectrum team would/do need to have with civil users. The MOD spectrum is a small team and staff numbers are unlikely to increase to facilitate access to civil spectrum bands. Therefore, it will likely remain a barrier that MOD to manage multiple relationships with lots of different civil licensees.

However, in practice the MOD has accessed civil bands in the recent past and conducted negotiations with the MNOs to use harmonised 3GPP spectrum in certain locations. This was explained during the workshop held with the MOD as part of the project. The issue that would remain is if MOD wished to increase its use of sharing with civil users in a range of different bands, then this might be a stretch on the available resources and the licensing process that can be used by Ofcom. At present the local access licensing process is used for accessing MNO spectrum by MOD, the feedback on this process from the MNOs indicated that the process is 'clunky' and not really fit for purpose. The main reason is due to the non-standard use of the civil spectrum by MOD and the amount of time it is used for, so their use does not quite fully align with the expectations of the licence process.

We would therefore consider that, as part of a future framework, MOD puts in place a process for handling access to civil bands. The process would need to consider the roles, responsibilities and actions between MOD, Ofcom and civil user that can fit within the overall framework based on the considerations listed in the previous section.

The process should also consider time limits for agreement and process for sign off and agreement by both parties before a licence to use the spectrum by MOD can be issued.

7.2.3 Barriers for more long term framework or strategic implementation such as DSA

In discussion with the MOD and stakeholders, it was clear that an appropriate and flexible framework would be needed to create a formal system for defence-controlled spectrum sharing. There are a number of benefits for creating such a framework that we discuss later. One of the key drivers for such a framework is so that it can be future proofed at the design stage. This means ensuring that whatever new technologies emerge or bands that are proposed for shared use could be incorporated into the framework.

For example, Dynamic Spectrum Access has been implemented in a number of civil bands such as in UHF using white space databases, Automated Frequency Coordination in the 6 GHz band for standard power Wi-Fi and CBRS in the use in 3.5 GHz (noting this is a special national case). We assume, based on many such examples, that DSA will become more commonplace over time as it becomes harder to share spectrum in congested bands and as spectrum scarcity increases.

In turn, we consider the different barriers that may arise for future proofing the framework for the long term. A list of particular barriers are highlighted below:

- Uncertainty of when and how DSA may be implemented for shared spectrum use with MOD
- Availability of suitable spectrum sharing systems that can be used by MOD
- Expertise and resources within MOD to manage the DSA design, implementation, and ongoing maintenance

Similar to the other barriers there is an issue with resourcing and expertise in managing and maintaining specific dedicated systems and solutions for spectrum management. It will be critical to include, or design into the framework such skills and expertise within MOD even to manage the likely external contractors that will operate the DSA database.

Overall, the barriers, challenges, and risks to sharing are centred around resource availability and expertise, timing, and alignment of enabling access and collaboration between respective parties and the MOD. The barriers are not necessarily technical, but some considerations should be given to the potential impact of interference to MOD use and how it is mitigated. We further consider that these barriers are not insurmountable and should become part of the requirements for developing the defence-controlled sharing framework as discussed later in the report.

7.2.4 Barriers and challenges in identifying suitable bands for sharing

There are numerous barriers and challenges in identifying suitable bands for sharing between MOD and civil users. This issue also considers the practicalities of not just identifying the bands but also the approach and processes in making the bands available to civil users, on the basis of the current approach to sharing with MOD.

At present and in general the approach by a civil user to MOD to request access is not simple or clear. In practice, it is often a non-transparent process to even know:

- If a band has been identified for possible sharing
- When it is likely to become available
- What the process is for making contact and requesting access and subsequently enabling access through the Ofcom licensing process

The process for new players for accessing the band is a challenge as there is no formal process and typically the user would approach Ofcom to request access, who in turn might pass this on to the MOD. More established users such as the PMSE industry, MNOs, or the utilities are much more familiar with the process in approaching the MOD for shared access. This is sometimes facilitated by Ofcom or, in the case of PMSE, a very straightforward, well established process in terms of access to particular bands.

Another challenge is the requirement for the MOD to analyse the potential for sharing in each band. This requires time, effort, and resources to identify and characterise individual MOD usage for each one. This would be relevant for new bands and MOD would rely on demand from users to express interest in these bands and may require justification for the access depending on how important the band is for defence usage.

We also consider the potential misalignment in timescales between civil demand and MOD usage/timeframe. For example, a good alignment might be when a MOD band becomes lightly used over time but there is no great interest from civil users as there might not be the technology or applications that could use it. In contrast, if there is extensive MOD use and significant civil demand this could prove to be a significant challenge in enabling sharing in such bands. This type of misalignment is becoming apparent for the proposed IMT bands (78/ GHz for example) at WRC-27.

8 Scenarios to consider for sharing Crown spectrum

In this section, we explore the different potential arrangements and challenges for the different proposed sharing frameworks. The frameworks are based on known, pre-existing approaches to sharing, on the basis that they comprise some well-established processes that already meet some of the challenges for sharing set out by MOD.

We propose a number of different scenarios in order to explore their pros and cons, and the level to which they address the idiosyncratic nature of sharing MOD spectrum identified earlier in the report.

8.1.1 Scenario 1 – Maintaining the status quo (No change)

Scenario 1 involves maintaining the status quo, with no changes to the current spectrum sharing arrangements between the Ministry of Defence (MOD) and civilian users. These arrangements are handled on a case-by-case basis, usually with pre-arranged coordination. Any new use that does not fit within existing procedures requires a negotiation between MOD, Ofcom, and the prospective user.

This method has demonstrated some benefits, allowing certain applications (PMSE, EESS, fixed links) to operate in shared spectrum efficiently. However, it has also shown limitations, particularly in permitting broader access by some users even when such use would appear to impose no coexistence threat.

The justification for this approach lies in the limited and highly specific demand, which can be managed effectively on an individual basis, though it may limit broader spectrum access and innovation. This approach is labour intensive for any new use. If demand increases in the future this could become a costly approach.

We assess the pros and cons over the technical, procedural, and legal/regulatory factors in relation to this scenario:

Technical	Procedural	Legal/Regulatory
Pros: Well-established technical coordination calculations between existing incumbents and MOD services **Cons**: Technical analysis done on a case by case basis depending on users/usage. It is not well suited to innovative new users.	**Pros**: Well-established and generally simplified process. Able to support the short lead times and suited to short duration use for some users (e.g. PMSE). **Cons**: A slow, manual, and administratively burdensome process, requires close and regular interaction with Ofcom on the fundamental sharing elements. It is resource intensive and relies on specific knowledge of individuals with a risk of losing such skills with individuals leaving, retiring or moving on to new roles It is not well suited to innovative and new users, as well as large scale new use.	**Pros**: Operates under the current legal framework underpinned by WT Act **Cons**: None

Evaluation outcome: This scenario works for pre-coordinated (PMSE) and other existing assignments, but it does not suit new users/applications that do not fit the established conditions and procedures, including short-term use. It does offer limited visibility and transparency (for example, it is not known

how many assignments are authorised or not fulfilled with this arrangement). This scenario would be appropriate only if there is such little demand from civil users to warrant any further enhancement.

Under this scenario, it has been difficult for mobile operators to access spectrum in a way that benefits both the MOD and MNOs. Other services attempting to access spectrum have also faced challenges, indicating that a change in the current approach could improve access for new users. The MOD has acknowledged that it has limited sharing due to barriers (such as pre-coordinated sharing) that only suit certain users. Therefore, it does not align well with the MOD's desire to formalise and enhance today's approaches to sharing spectrum in the UK.

8.1.2 Scenario 2 – Extension of Ofcom's Shared Access Licence principles to Crown spectrum for all new applications

In this scenario we propose an extension of Ofcom's SAL framework principles to include MOD shared bands. The reason for this proposal is because the SAL framework has proven effective in meeting the demand from localised and area-specific users in bands supporting IMT technology.

Key objectives of this scenario are the following:

- Support novel use without additional burdens, enabling quick coordination to support commercial timeframes without prolonged consultation
- Ensure equal opportunity for access to any potential users, and retain existing processes (as necessary) where arrangements are currently fit for purpose (PMSE)
- Streamline sharing frameworks, including permit a formalised method in which licensees can be informed to stop transmissions if required by MOD (in MOD spectrum)

Looking ahead, the MOD might consider adding more frequency bands on an incremental basis. This approach aims to balance the needs of both MOD and civilian users without any major legislative and procedural changes.

We consider some of the technical, procedural, and legal/regulatory factors in relation to this scenario:

Technical	Procedural	Legal/Regulatory
Pros: More efficient coordination between different services and more intensive use of available spectrum **Cons**: It will require knowledge and ability, and possibly additional resources, to determine coexistence between a wide range of applications and MOD uses in all Crown bands.	**Pros**: Take up the existing or improved procedures within the SAL framework, would mean limited interaction by civil users with MOD or Ofcom and rely on the established application process (which will evolve to online applications) Civil users gain access to spectrum via Ofcom regardless, whether in civilian and Crown spectrum. **Cons**: Users will have more restricted use conditions than a standard Ofcom licence. There may be additional resources required from MOD and Ofcom to develop and implement new procedures and coexistence evaluation methods. MOD lose control of specific procedures they may wish to retain as part of the process. MOD could also lose some of the influence of development of the framework to meet their needs. It is unclear how existing sharing arrangements will fit into this framework, i.e. PMSE. This will depend upon and may need adaptation of Ofcom's internal procedures.	**Pros**: Non-Crown usage of spectrum is wholly under the remit of Ofcom. It maintains the separation all non-Crown usage of spectrum is wholly under the authorisation of Ofcom **Cons**: This may require some changes to the current legal status, thus incurring time and cost for adjustment and potential challenges in setting out the specific legal requirements Some users may need to lose access to spectrum if there are other civilian higher priority needs eg. PMSE demand for unplanned national events, such as Coronation or State funeral. This may be covered under the conditions imposed for use of any MOD spectrum.

Evaluation outcome: Expanding the principles of the existing Ofcom SAL framework will require detailed consideration. There are complexities, cost, and time impacts. Establishing the sharing conditions, which can be processed without manual intervention and still retain an element of obfuscation, will impose a burden on the MOD – who will not benefit by 3rd parties using 'their' spectrum – but should be beneficial to spectrum users in the UK.

However, on the positive side civil users will be familiar with the process and could bring spectrum into use quite quickly. Civil users would have a one-stop-shop for spectrum access. We assume any licence costs would be less than other SAL bands since more restrictive conditions will be imposed. Users would need to specify their spectrum availability requirements to help decide if access to MOD spectrum is likely to provide sufficient quality. It may be useful that this assessment and information gathering begins before any implementation to assess the credibility of the demand for the restricted availability of spectrum (for a prolonged period) that would exist in MOD spectrum.

The SAL framework also offers the potential to be future proof for MOD bands and would mean that the future evolution of the system would follow Ofcom's evolution of SAL (including standardised sharing

mechanisms and equipment standards, and potentially more dynamic approaches). MOD would need to monitor to ensure that their use conditions and need for obfuscation are maintained.

8.1.3 Scenario 3 – Automated Dynamic Spectrum Access

This approach could enable the most intensive and efficient sharing if supported by the wide range of technologies involved. It is not known how any device coordinated sharing would respect MOD's requirements for pre-emption and obfuscation. Hence, we have assumed that a MOD condition compliant DSA solution would be a dedicated geo-location database that would require devices sharing in MOD bands to be able to connect with the database for real time situational updates and authority for spectrum use. This type of DSA solution is not new and there are existing solutions developed around the world including Citizens Broadband Radio Service in the US, Whitespace Databases (e.g. databases in use in the US, Singapore, and South Africa) and Automated Frequency Coordination for the use of standard power Wi-Fi in the upper 6 GHz.

However, it will demand significant investment in a new highly specified system and collaborative efforts from both the private and public sectors. A critical challenge in this scenario will be the availability and accuracy of data, as the system's effectiveness relies heavily on real-time information about spectrum usage by the MOD and civil users. There is also a consideration of national vs international implementation and that globally harmonised solutions would offer economies of scale at both the database and device level.

We consider some of the technical, procedural, and legal/regulatory factors in relation to this scenario:

Technical	Procedural	Legal/Regulatory
Pros: Extensive development of new DSA type database with designed protection of MOD uses and capable civil equipment. Will require competent, security cleared solution provider. **Cons**: Will need to develop new algorithms for sharing in a dynamic way which could be complex. The cost burden would impact all devices – but any benefit would be borne by those gaining access. The demand must warrant this.	**Pros**: Minimal human intervention besides maintenance and management of the database (commercial operation) once implemented. Sophisticated application portal for civil users and real time access to spectrum. **Cons**: Interaction with the tool by users may be far too sophisticated than necessary for the required level of sharing. 'Bad actors' could use information gleaned on spectrum availability / non-availability as indication of MOD activity.	**Pros**: None. **Cons**: This may require some changes to the current legal status, thus incurring time and cost for adjustment and potential challenges in setting out the specific legal requirements.

Evaluation outcome: MOD has previously considered developing its own Dynamic Spectrum Access system. The idea did not gain traction for several reasons, most notably cost, but also lack of justification for the need of a sophisticated tool for the limited level of demand and need for sharing being proposed. This remains the same today and we have found no significant demand for using MOD shared spectrum, which in turn impacts the justification for developing a potentially costly DSA system. Nevertheless, we must also consider the potential future demand for MOD shared spectrum and how a DSA system would offer a future-proof approach to spectrum sharing. It should also be considered that if a globally harmonised solution were to emerge at a reasonable price point and with demonstrated benefits such as timesaving, cost saving and more efficient use of spectrum, the DSA option may look more attractive. However, until that point, we consider this option to be unable to deliver the benefits at a reasonable cost due to current limited demand.

8.1.4 Scenario 4 – MOD as a Spectrum Management Organisation

In this scenario we assume that MOD becomes a Spectrum Management Organisation (SMO), although whether as a result of needing to manage sharing or as a result of internal need to manage Crown users in a way more akin to that of an SMO is not relevant here. We also assume that the function is limited to spectrum management in a way similar to that of the energy utilities and their SMO the Joint Radio Company (JRC), who manage spectrum in a limited and specific way, mainly based on the distribution of authorities within the terms and conditions of an Ofcom Area Defined licence.

As explained earlier, we do not envisage NTIA (USA government spectrum management vs. civil FCC) functionality.

This scenario considers MOD utilising an ability to issue an 'Authority to Transmit' under their overarching Crown Spectrum Access '. We assume that MOD would be issuing these ATTs themselves, based on their own criteria for sharing, using parameters specific to the sharing envisaged. There is no obligation for MOD to publish these agreements, nor for MOD to open options for others to share spectrum under

the same parameters, or even offer it up for auction, as it would be if Ofcom were managing under their obligation for openness, which can be a stumbling block in some cases.

The benefit of MOD becoming an SMO is that they retain full control of shared usage in MOD bands. This includes where and when a user may transmit and ultimately turn off access to civil users whenever spectrum is required by MOD. This could be considered an extreme case, as it requires significant management overhead, would be resource intensive, and require new skills and competencies to be developed within the spectrum department of MOD. It would likely take time to create and require buy-in from other government departments such as DSIT and the Treasury. However, we also envisage the first point of contact for prospective civil users to be Ofcom, acting as a gateway for civil users to access MOD. We do not believe that civil users should or need to approach MOD directly.

A balanced assessment should be made of demand for shared MOD spectrum versus creation of such an SMO because, as discussed in the report, demand is limited at present. Nevertheless, we assess the pros and cons of setting up an SMO below.

Technical	Procedural	Legal/Regulatory
Pros: Will require dedicated technical resource to carry out sharing assessments (most likely using pre-existing software tools), and grant Authorities to Transmit to users. **Cons**: Will require skilled and trained technical resource with the need to program (or likely define) solutions into dedicated software tools	**Pros**: Provides MOD with full control over the sharing framework requirements and conditions for the end to end process with fine granularity. **Cons**: Resource intensive with multiple skillsets required from an administrative perspective to issue authorisation to transmit to users, collect fees and to monitor the process, ensure/enforce correct use of frequencies. It is assumed that (many of) these skills already exist in MOD since they are able to manage their internal users effectively. Currently Ofcom manage PMSE access to MOD spectrum – the formation of a separate SMO for managing MOD spectrum will impact this	**Pros**: None **Cons**: It is not entirely clear whether Crown Spectrum Access is analogous to an Ofcom Area Defined licence (Land Mobile) and that MOD can legally issue Authorities to Transmit under their arrangements. This would need to be investigated, although there is no reason why MOD cannot manage the whole process and Ofcom issue the ATTs on their behalf.

Evaluation outcome: The Authorisation to Transmit (ATT) model is not a new concept. For example, the Joint Radio Company (who issue licences to utility companies) and the CAA (who issue licences to aviation/aeronautical companies) have the right to issue ATTs. Therefore, the concept could be extended to the MOD enabling them to grant such ATTs to civil industries to share MOD spectrum. However, there are some major consequences of effectively setting up as a Spectrum Management Organisation. First and foremost is the cost of setting up a dedicated organisation and also the legal, commercial, and structural issues.

There is also the consideration of alignment of skills and competences. There will need to be trained staff, not just at a technical level but there will be the administrative and finance functions to consider, together with IT and security considerations, which will be extensive. . A key benefit is that MOD will retain full control and management of shared spectrum (setting all the appropriate conditions of use including notified service interruptions) and would need to also somehow bring an enforcement element (most likely provided by Ofcom) when 'licensees' do not abide by their ATT conditions.

The most uncertain element of MOD becoming an SMO is the fee charging aspect, which will have some commercial implications.

8.2 Assessment of the four candidate scenarios

It is clear that none of the scenarios discussed above provide a simple solution that addresses all of the 'Considerations and Barriers' identified in Section 7. It is also worthwhile noting the limitations of this current study: it has been done with a modest budget, in a short time scale, and it is likely that any preliminary findings will benefit from a rigorous review from a wide range of stakeholders.

Notwithstanding the limitations of being able to advocate a strong preference for any preferred solution, it is likely that there are key aspects which will require consideration by, inter alia, DSIT, MOD and Ofcom, before significant clarity on a preferred direction could be established. A key concern in proposing any change in the approach to sharing MOD spectrum is the apparent lack of demand that would justify the effort and cost of any change or result in any significant improvement in spectrum use. This needs to be verified to assist any detailed consideration of selecting a preferred migration.

- Maintain the status quo: This works at the moment – but fails to address the specific MOD desire to formalise and enhance today's approaches to sharing spectrum in the UK.
- Extension of the principles of Ofcom's SAL: Ofcom's vision for the SAL framework, including harmonisation and standardisation, and the benefits of one body to handle access to spectrum for all civil spectrum users has much to commend. Extending the SAL to include non-IMT uses, and the technical requirements for managing more complex coexistence scenarios and operation of licences with different conditions of duration and use (including terminating use at short notice) are a significant deviation from existing practice.
- Automated Dynamic Spectrum: There is significant overhead (and cost) in developing a DSA system to perform this task. An overhead would be imposed on all civil devices seeking to operate within this regime. MOD would need to monitor / assess short term use and develop methods to preclude 'bad actors' gaining insight into their activity.
- MOD as an SMO: This option is more strategic that the other 3. Strategic aspects of this option could justify its adoption irrespective of demand – but would impose additional burdens on MOD, and possibly Ofcom.

We describe in the next section the recommendations for further development and study and highlight some of the implications in doing so.

9 Recommendations

Based on the foregoing, we recommend the following:

- We have identified that demand for new use of MOD spectrum by civil users is limited.
  - We recommend that any expansion to other uses or applications can only be merited if there is sufficient demand, and any expansion should be incremental.
  - We recommend that the level of demand for access to MOD spectrum by any new users (ie not PMSE, Radio Amateur or Fixed Links) be verified, possibly by Ofcom.
  - We recommend that information gathering begins before any implementation to assess the credibility of the demand for the restricted availability of spectrum (for a prolonged period) that would exist in MOD spectrum
- We note that the existing sharing of MOD spectrum (notably PMSE) works effectively
  - We recommend that any change to the sharing regime should not prejudice existing sharing.
  - Ofcom should review the benefits, or otherwise, of streamlining/integrating sharing approaches into a common framework.
- Some potential users of spectrum in the UK have been unable to gain access to spectrum. We believe that the application process and responsibility for handling applications are not clear to potential applicants.
  - We recommend that Ofcom should be clearly identified as the body that manages access to MOD spectrum for civil users, and for all users (civil and Crown) for access to civil spectrum.
  - We recommend that Ofcom should monitor and publish any applications for spectrum that are unable to be supported in order to assess if any improved sharing in MOD spectrum is a priority.
  - Any required coordination between MOD and Ofcom can and should be handled between them, and their decision on sharing conditions would be provided to the applicant – not the rationale. This will provide MOD a level of protection and security.
- To facilitate sharing between civil and Crown users:
  - We recommend that MOD develop a comprehensive spectrum roadmap identifying current and future use. This will consider potentially long military equipment lifecycles, emerging technologies, operational needs, and international regulatory developments such as WRC27.
  - We recommend the identification and formalisation of the roles within Ofcom and MOD involved in managing and maintaining any new framework.
  - We recommend that Ofcom and MOD identify spectrum constraints and agree methodologies to allow sharing. This will include building up a set of sharing rules or coexistence approaches that Ofcom can utilise in assessing suitable sharing arrangements.
  - UK MOD to continue to widen engagement with other government agencies, private stakeholders and academia to advance and monitor development of sharing technologies

- Recognising the benefits of harmonisation (at an equipment, regulatory, and management level), we see the potential adoption of a future agreed sharing framework within CEPT ECC PT1 as extremely useful.
  - We recommend that, MOD and Ofcom remain active in regulatory and policy fora and seek to incorporate agreed best practice in future sharing frameworks.
  - We recommend that MOD share the outcomes of this study with friendly/NATO countries and acknowledge the parallel work within CEPT that could yield benefits to the wider defence community in the same way but considering key defence requirements.
- Planning and analysis for WRC27 will be a significant task, requiring specific and detailed knowledge of existing and future spectrum use (MOD and civilian).
  - We recommend that sufficient resources (both Ofcom and MOD) should be put in place to support this activity.