Space Spectrum Management

Foundations for an informed policy discussion towards WRC-23 and beyond

ESPI European Space Policy Institute

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1 Introduction

In today's world, **the role played by wireless communication is becoming exceedingly crucial.** Devices of different kinds, which rely on wireless networks to work, are an integral part of our everyday life: from smartphones to Near Field Communication (NFC) and Radio-Frequency Identification (RFID), including tools such as remote controllers or wearables.

Radio spectrum availability is the backbone of the digital economy, with the full portfolio of space applications being no exception. Both the operation of satellites and the provision of services intrinsically relies on wireless communication. Space operations can only be conducted in a reliable manner, provided that access to required spectrum bands is granted, and their use is ensured free of interference. Indeed, Telemetry, Tracking and Command (TT&C) transmissions require specific (and usually different) frequency bands for both the uplink and the downlink data transfer. Similarly, radar or Radio Frequency (RF) monitoring systems conducting Space Situational Awareness (SSA) are underpinned by a licensed use of spectrum. Moreover, **frequency bands are essential for satellite operators to generate value from services** such as television broadcasting, Internet of Things (IoT) connectivity, satellite Positioning, Navigation and Timing (PNT) information, broadband communication, weather forecasting, and active and passive remote sensing.

Whilst frequency bands are crucial enablers of space activities, **spectrum is a valuable, scarce, and finite resource**. Moreover, the use of frequency bands for satellite missions must coexist with the need for spectrum of other applications and services, a fact that makes spectrum availability even more limited. In this regard, regulatory decisions are needed to further ensure an effective and efficient use of frequency bands for all, protecting space data transfer against interference with other spacecraft, ground stations or terrestrial applications. Thus, the utilisation of most spectrum bands requires highly competitive and complex allocation, coordination, and planning frameworks.

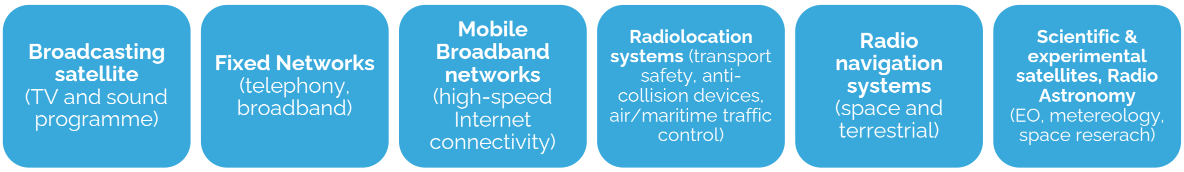

Figure 1: Radio communications terminals in the Information and Communication Technologies ecosystem

This Report aims to explain the topic and focus on the crucial policy dimension of spectrum management in outer space, while also investigating **how spectrum management systems could be enhanced to more effectively and efficiently deal with the currently congested space and spectrum environment and the demand for a more connected world.**

Chapter two will provide an overview of the outstanding dynamics within the satellite communications sector, followed by an assessment of the changing societal and economic value of spectrum, covered in Chapter three. An overview of the ITU system and of national assignment and licensing procedures for space systems is presented in Chapter four. An analysis of selected policy and regulatory challenges and their implications in the lead up to the WRC-23 for space services will be presented in Chapter five. Chapter six provides an overview of the European regulatory framework, whilst Chapter seven posits a European policy perspective and proposal for spectrum policy. A description of the international spectrum management regime and European spectrum regulatory environment is included in Annex B, and an overview of WRC Study Groups and Agenda Items in Annex C.

The Report benefitted from the review of external experts, and interviews with selected stakeholders ranging from international organisations to national entities, relevant industrial actors and academia (See Acknowledgments).

2 THE LONG-TERM VIABILITY OF THE SPACE SECTOR

The space sector is experiencing rapid evolution, with the **satellite communication application playing a central role** in this development in both Europe and worldwide. Indeed, as **space is increasingly becoming part of the broader digital infrastructure**, with satcom services integrated into terrestrial networks and providing solutions across various industry and market verticals.

Overall, **the global satellite communications sector is undergoing significant transformation**, as market and technology forces converge, and newer value propositions and user requirements emerge. Changes are witnessed on the demand side, stemming from the digital revolution, with the emergence of new connectivity needs and requirements. For instance, Over-The-Top (OTT) services are offered through the Internet by operators such as Microsoft, Amazon and Netflix, all of which predominantly rely on terrestrial infrastructure for their service provision.[1] This context is affecting the satcom market. While direct broadcast services (DBS) and direct-to-home (DTH) television traditionally represent the largest portion of the downstream segment of the space economy ($89.9 billion as of 2022, Space Foundation), revenues from these services have witnessed a slowdown over the past decade, with falling prices resulting from oversupply. This is due to a **major shift from DBS and DTH services to non-linear television, notably driven by Video on Demand (VoD).**[2]

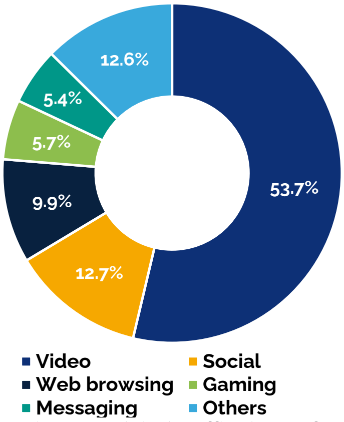

Figure 2: Global traffic share of different services, 2021 (Credit: Axon based on Sandvine)

This changing market demand pushes satcom operators to respond to the need for wider access and higher data rates by relying on new solutions, including larger satellites integrating maximum capacity, such as **Very High Throughput Satellites (VHTS), and Ultra High Throughput Satellites (UHTS) but also more flexible programmable satellites** (notably, constellation architectures using smaller and smaller satellites), and taking advantage of the decrease in costs. This facilitates the high-volume production required by large constellations to provide customers with the capacity to adapt to the evolving market demand. The necessity for increased transmission capacity requires tapping into larger bandwidth and therefore higher frequencies.

In parallel, the above-mentioned trend in the satcom sector is creating a progressive trend of **shifting from pure Geostationary Orbit (GSO) to complementary or alternative Low Earth Orbit (LEO) connectivity.** This is due to the low latency, and consequently better user experience, required by new online activities such as video conferencing and live-streaming, cloud-based applications, telemedicine, real-time gaming, transportation management, emergency response, and High Frequency Trading.[3] Indeed, only the shorter distance to LEO with respect to GEO allows such a reduced latency in data transmission, despite requiring the deployment of large constellations instead of single satellites for coverage reasons. This implies a **change of the usual architecture of satellite infrastructure**, as well as for the satellite manufacturing industry. In the non-GSO regime, especially LEO, the **large constellation sector is developing as a source of growth and disruption**. New space actors with strong financial support are emerging at unprecedented levels of innovation, as new models of development and a shift of risks and responsibilities are being experienced. This paradigm shift is also evident in the fact that some **GEO**

[1] ITU defines OTT as "application accessed and delivered over the public Internet that may be a direct technical/functional substitute for traditional international telecommunication services". in "Collaborative framework OTTs". (Link).
[2] A. Tyagi & R. Sharma. 2019. "DTH Technology". International Journal of Engineering Research & Technology (Link).
[3] S. Spolitis et al. 2014. "Latency causes and reduction in optical metro networks". SPIE Photonics West OPTO (Link). This is also due to lower-cost and easier access to LEO in comparison to GEO.

satellite operators are moving from traditional GEO networks and services to a diversification of their infrastructure, increasingly cooperating with or acquiring new LEO and Medium Earth Orbit (MEO) entrants, as well as teaming up with traditional terrestrial telecom providers. The hybridisation (or consolidation) of networks allows satcom operators to provide solutions across various verticals, with the goal of capturing the fast-growing broadband connectivity market and tackling the expected booming demand for connectivity across a variety of sectors with diverse latency and transmission capacity (and therefore bandwidth) needs, such as aerial (e.g., in-flight connectivity), maritime mobility, land transportation in remote areas, fixed data, and government services. As an example, SES already pursued a multiorbital solution in 2020, after having acquired O3B and its MEO networks in 2016. Similarly, the **combination of Eutelsat and OneWeb, providing integrated GEO and LEO solutions and services, takes advantage of both the higher capacity offered by GEO and the lower latency offered by LEO satellites**.[4] This emphasises the high expectations traditional operators place on LEO and MEO connectivity, which is believed to become the new growth engine for the satcom business not only in Business-to-Consumer (B2C) markets but also, potentially, in the Business to Business (B2B) and Business to Government (B2G) markets. In parallel, recent examples of horizontal mergers, such as Viasat's acquisition of Inmarsat (in this case happening between two GEO operators) complete the picture suggesting a reconstruction of the ecosystem with fewer competitors.[5]

The approach developed by some new entrants, such as SpaceX, goes one step further and aims to establishes processes where the **connectivity solution is part of a vertically integrated market**, offering new combined services, such as autonomous driving.[6] In June 2022, the Federal Communications Commission (FCC) granted SpaceX authorisation to use its Starlink system on vehicles in motion. Further, the **direct satellite-to-device** (D2D) innovative business model is taking shape especially for emergency purposes. Indeed, D2D technology allows consumer smartphones to send messages directly through the satellite platform, thus bridging the gap between satellite and terrestrial mobile network operators. D2D market is forecasted as a significant opportunity in satellite communications, with projected revenue of $60 billion and up to 350 million subscribers by 2030.[7] Several IT companies such as Apple and T-Mobile US have entered the satcom sector. For example, Apple and Globalstar, a U.S company operating a suite of LEO satellites for voice and data services, agreed on a use of 85% of the satellite network capacity to provide "Emergency SOS By Satellite".[8]

New spectrum-hungry connectivity concepts are also emerging.[9] In particular, a profound transformation of business activities is the **result of the worldwide deployment of 5G in the 2020s**. Indeed, the 5G standard enables the first multi-technology network, making use of a set of dedicated technologies, leading to an increase in connectivity capabilities and services which require space solutions to be crucially integrated with terrestrial ones.

Overall, in a setting where traditional global terrestrial telecommunications infrastructure networks maintain their role in transmitting most data (including land-based delivery systems such as fibre optic, copper cable antenna sites or towers for terrestrial wireless communications), **space and terrestrial services are not mutually exclusive**. For instance, space-based assets are crucial when land-based systems are down, such as during natural or human-made disasters. But beyond

[4] Eutelsat. 2023. "Eutelsat and OneWeb combination heralds new era in space connectivity". Eutelsat (Link).
[5] J. Rainbow. 2023. "Satellite operators Viasat and Inmarsat complete merger deal". SpaceNews (Link).
[6] ITU/UNESCO. 2022. "The State of Broadband". Broadband Commission for Sustainable Development (Link).
[7] I. Suarez & C. Queiroz. 2022. "The Coming Era of Satellite Direct-to-Handset Connectivity". ViaSatellite (Link).
[8] R. Jewett. 2022. "Apple to Debut iPhone With Emergency Messaging Enabled by Globalstar Satellites". ViaSatellite (Link).
R. Jewett. 2022. "Apple Says SOS Via Satellite is Now Available via Globalstar Satellites". ViaSatellite (Link).
[9] ESPI. 2020. "ESPI brief No.37: Rethinking the assessment of the value of spectrum". ESPI (Link).

backing terrestrial systems with the space-based infrastructure, the latter could represent a turning point in providing coverage to less densely populated regions or areas of low terrestrial penetration, where deploying terrestrial infrastructure is costly and time consuming.[10] Thus, a technology mix is critical in providing the most affordable solution possible, depending on each case, seen by new players such as mobile network operators entering the satellite ecosystem.

Bridging the Digital Divide: What is the Role for Space?

Broadband connectivity has become an essential component of everyday life worldwide, benefitting global trade, health, employment, learning and social cohesion.[11] This trend is substantiated by the double-digit annual growth of Internet users (11% growth in 2020, with a peak of 15% in low- and middle-income countries), with an acceleration during the COVID-19 pandemic.[12] Whilst access to broadband has become a relevant factor considered by policy makers worldwide, as of 2022, **only around 66% of the total population were reported to have access to the Internet**, with about 2.7 billion people without the possibility to make full use of broadband connectivity services, including in Europe.[13] In Europe, the share of households with Internet access has risen in 2022, but 7% of them still lack broadband connectivity.[14]

Bridging the digital divide between remote and urban areas is made arduous by high costs of serving hard-to-reach and low-populated areas, and the consequent low return on investment (also, considering aspects related to the low Average Revenue Per User - ARPU). This data should be read in parallel with analysis provided by the World Bank, which identifies **a positive impact of increasing broadband penetration on GDP growth** (e.g., 1.38 point of GDP growth for every 10% increase in access to broadband connectivity for low- and middle-income economies – reduced to 1.21 for high-income economies).[15] **Satellite-based broadband has the advantage of being quickly deployable, no matter how remote the area is**.[16] Furthermore, satellite broadband is more cost-effective in areas without terrestrial infrastructure. In Africa, Eutelsat is a leading operator, connecting over 200,000 users with their Konnect satellites[17].

The European Commission (COM), the European Space Agency (ESA) and national governments are recognising the potential benefits of space-enabled broadband connectivity to complement existing terrestrial infrastructure towards higher European competitiveness and societal progress.[18] Indeed, the use of a range of solutions, embedding the space-based component, seems consistent with COM's recent commitment to developing adequate frameworks so that "*all market players benefiting from the digital transformation (…) make a fair and proportionate contribution to the costs of public goods, services and infrastructures.*"[19]

Within the overall picture, a crucial role will be represented by the recent adoption by the EU Council of the Regulation for the development of IRIS², notably representing the EU constellation giving a response to the security needs that come into play with the spread of broadband connectivity.[20]

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[10] ESOA. 2017. "Satellite & Spectrum: The Right Wavelength". GSOA (Link).
[11] M. Young & A. Thadani. 2022. "Low Orbit, High Stakes". CSIS Aerospace Security Program (Link).
[12] ITU/UNESCO 2022. "The State of Broadband". Broadband Commission for Sustainable Development (Link).
[13] ITU data in: ITU/UNESCO 2022. "The State of Broadband". Broadband Commission for Sustainable Development: 2 (Link).
[14] Eurostat. 2023. "Digital economy and society statistics". Eurostat (Link).
[15] C. Qiang et al. 2009. "Economic Impact of Broadband". In Information & Communications for Development (Link).
[16] ITU/UNESCO 2022. "The State of Broadband". Broadband Commission for Sustainable Development (Link).
[17] M. Holmes. 2023. "Eutelsat hits milestone of connecting 200,000 people in Africa." Via Satellite (Link).
[18] COM. 2020. "Facing the challenges of broadband deployment in rural and remote areas". COM (Link).
[19] COM. 2023. "European Declaration on Digital Rights and Principles for the Digital Decade". COM (Link).
[20] Representation in Cyprus. 2023. "Commission invites the industry to submit proposals to deploy the new EU secure connectivity satellite constellation, IRIS²". COM (Link). And COM. 2023. "Reg No 2018/1046". TED (Link).

3 THE VALUE OF SPECTRUM AND ITS EXPLOITATION

The **use of the radio frequencies depends, among other factors, on their intrinsic physical characteristics,** including the propagation properties or wavelength, and the technical requirements of their use being more suitable for a particular type of communication service.[21]

When focusing on space telecommunication, there are physical limits to the use of electromagnetic waves as the atmosphere absorbs certain frequencies, preventing the signals emitted from Earth to reach satellites and vice versa. Therefore, the only two portions of the electromagnetic spectrum that are open to space are the visible bands (for which solutions meeting high technical requirements are still under demonstration and not yet deployed) and the part of the radio spectrum that goes from approximately 30 MHz to more than 50 GHz. Space communication uses bands from Very high frequency (VHF) to Ultra high frequency (UHF), as well as Super high frequency (SHF) band and the lower portion of Extremely high frequency (EHF), also known as L, S, C, Ku, Ka and Q/V bands.

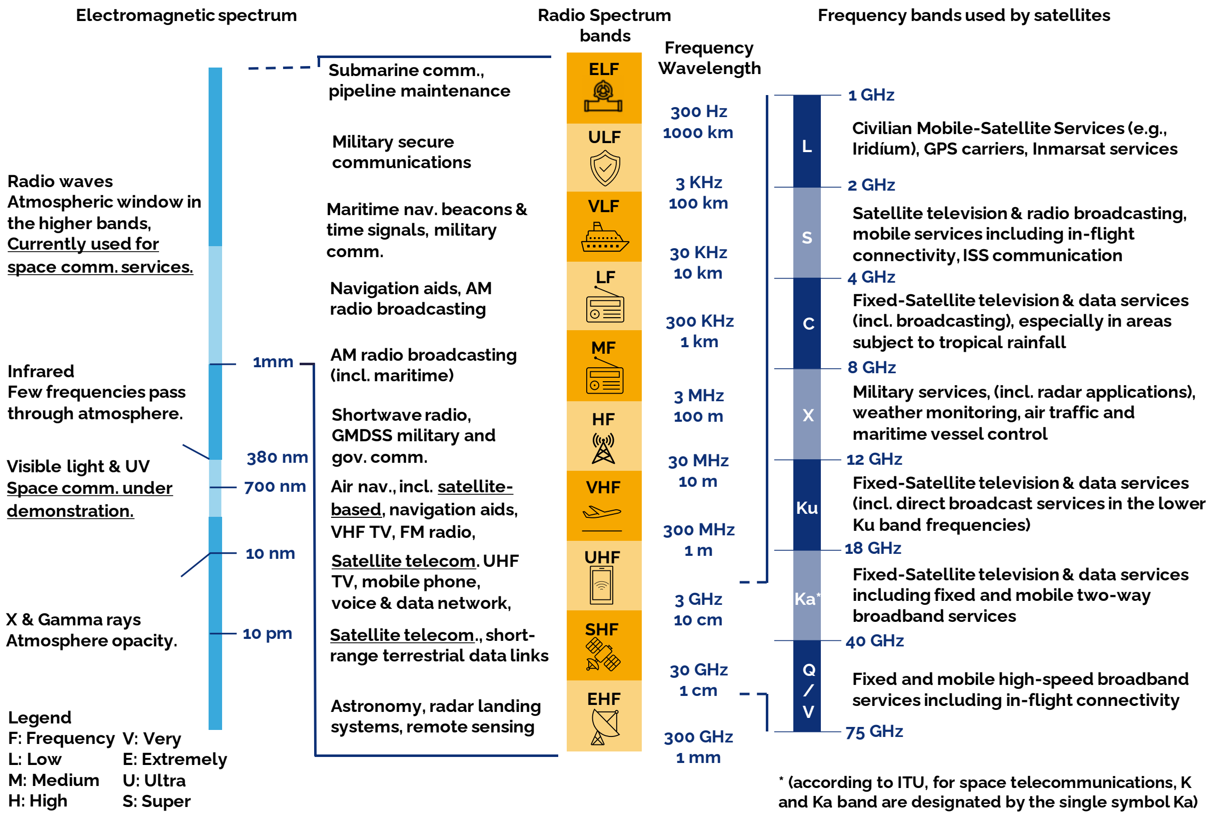

Figure 3: Atmospheric Windows and Spectrum bands used for satellite telecommunication (Credit: ITU, GSMA, ESPI)

The last decade has witnessed the advent of satellite constellations, operated or proposed by both governments and commercial entities. Several space actors have announced their plans to develop large, multi-satellite infrastructures, especially in LEO for different purposes, thereby showing an interest in getting access to significant portions of the radio spectrum, particularly at high frequencies in Ku and Ka or even Q/V bands.[22] Some first operational satellites have been deployed by SpaceX making use of the E band for experimental purposes, which follows the V

[21] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 26-27, See Footnote 14.
[22] I. del Portillo et al. 2018. "Ground segment architectures for LEO constellations with feeder links in EHF-bands" (Link).

band in the 75-80 GHz.[23] These constellations are composed by a batch of satellites at, at least, a magnitude larger than the satellite constellations deployed by Iridium, Globalstar and Orbcomm in the late 1990s, and occupy orbits between approximately 500 and 1.500 km.[24] SpaceX has launched over 4,800 operational satellites. OneWeb has launched 618 first-generation satellites into orbit, thus reaching completion of its constellation. More broadly, more than 1.7 million non-GSO satellites, planned to be launched by 2030 according to the filings made with the International Telecommunication Union (ITU).[25] The envisioned systems range from dozens of CubeSats to thousands of satellites to be manufactured and launched during the 2020s, targeting exclusively non-GSO. This includes Amazon´s plans to launch over 3,000 satellites as part of its Kuiper constellation and SpaceX Starlink approved by the FCC for the launch of 7,500 next-gen spacecrafts for upgrading its constellation.[26] In 2021, E-Space made a regulatory filing through the government of Rwanda for two ITU-filed narrowband networks, called Cinnamon-217 and Cinnamon-937, comprising some 327,320 satellites in 27 orbital shells broadcasting in both L- and S-band. More recently, the company filed registration through France's National Frequencies Agency (ANFR), for a fully C-band constellation, called Semaphore-C, and consisting of 116,640 satellites in 810 orbital planes.[27]

However, **both orbits and spectrum are limited natural resources**. This is mostly due to physical/engineering limitations of using frequencies, and the hardship of coexistence between services; this also implies a maximum of constellations that could be deployed because of spectrum availability. As it will be explained in the following Chapter, ITU has identified radio frequencies and any associated orbits, including GSO, as a limited natural resource in ITU Constitution and Convention (CC) Article 44 and the Radio Regulations (RR).

The increasing use of space has led to a higher congestion of Earth orbits and a **growing demand for access to radio frequency spectrum bands for satellite applications**. The rising demand for spectrum by new competitors elevates the risk of spectrum shortage, as well as the **urgency of securing spectrum bands for satellite systems**. Overall, the satellite connectivity market is projected to triple, from $4.3 billion to $16 billion by 2030, and the share taken by non-GSO solutions, mostly captured by LEO constellations, is expected to grow 2.5 times faster than the total market, representing almost 50% of it by 2030. In addition, for instance, the satellite IoT market is projected to reach $8.7 billion by 2032,[28] and spectrum management should allow this prospective growth.[29]

New concepts, technologies and activities are expected to squeeze various novel types of services (e.g., high altitude platforms, intelligent interlinked transport systems) into existing frameworks. This is reflected in the ongoing debate between spectrum mangers on how to use this limited resource rationally, efficiently, and economically. This also leads to candidates competing for the same spectrum rights and contributes to serious concerns of interference, even among different types of applications.[30] This demand requires a new allocation of frequency bands, with the setup of mechanisms to ensure coexistence,[31] or incumbents to optimise and free up spectrum already allocated (See Thematic Box: C band Relocation in the U.S).

[23] NTIA. 2023. "Development of a National Spectrum Strategy". NTIA (Link).
[24] JASON. 2021. "The Impacts of Large Constellations of Satellites". National Science Foundation (Link).
[25] UN. 2023. "Our Common Agenda Policy Brief 7: For All Humanity – The Future of Outer Space Governance". (Link): 5.
[26] C. Henry. 2018. "FCC approves SpaceX, Telesat, LeoSat and Kepler Internet Constellations". Space (Link).
[27] P. De Selding. 2023. "E-Space registers 116,640-satellite C-band network with ITU through France". Space Intel (Link).
[28] Allied MARKER Research, Satellite IoT Market Research, 2032 (Link)
[29] J. Fagerberg. 2023. "The Satellite IoT Communications Market". Berg Insight (Link).
[30] ESPI. 2020. "ESPI brief No.37: Rethinking the assessment of the value of spectrum". ESPI (Link).
[31] See for instance in this regard European Radiocommunications Committee. 1999. "ERC Decision (99)06". CEPT (Link).

In parallel to the increasing demand for spectrum, **new (cost-effective) technologies are making it possible to ensure that available spectrum is used (and shared) efficiently**, **and to enable the use of other portions of the spectrum** (with larger bandwidth). An example is represented by tools for dynamic spectrum sharing, enabling more than one user to operate on the same band without interference through a centralised coordination access based on primary or secondary users.[32] Nevertheless, among other concerns, constraints related to the need to share confidential information between operators could arise.

In addition, mainly because of increasing congestion in lower frequencies (L, S and C bands), as well as migration due to 5G or 6G deployments, satellite operators are moving to higher frequencies (Ku, Ka) for TV and very-small-aperture terminal (VSAT) services, with service beams more focused on regional or sub-regional areas because of the reduced propagation characteristics. Such an evolution is reasoned by the fulfilling of a general need for higher data rates in all radiocommunication services, including Earth Exploration-Satellite Service (EESS) data, or Space Operation-related data, and the technology maturity for both spacecraft and terrestrial terminals which makes higher bands cheaper and easier even for less experienced operators as reliable commercial of the shelf hardware. While Ku band is becoming increasingly congested due to the deployment of large LEO constellations, Ka band is gaining popularity especially for user and gateway links, with higher risk of interference between close spacecrafts, also due to the smaller terminal antenna having wider beamwidths. Q/V band is also becoming of some interest for satellite operators, due to the higher bandwidth and higher data rate, as well as emerging uses of the E band, especially for feeder links.[33] The greater flexibility, including in terms of utilisation and transition to other bands, allowed by technological advancements, has drawn attention to the determination of **the value of spectrum as the core parameter driving spectrum management.**

Together with the aforementioned physical characteristics of each frequency band, other parameters such as its scarcity, variable market, economic rent, and strategic and regulatory aspects contribute to the determination of the value of spectrum and should be continuously **considered to ensure its rational, efficient and economical use** as part of the optimal spectrum management approach. **An analysis on the value of spectrum requires consideration** (or at least an estimate) **of both economic and social benefits**. The former could be quantified through the sum of the direct effect of the use of a spectrum band, the forward and back linkages on GDP and employment, or though measuring the consumer and producer surplus.[34] The latter are represented by the possibility to provide, for instance, education and training through broadcasting, or the availability of personal devices for home health and security. Attention to social benefits requires in some cases **limitations to the spectrum market** in scientific research. In this context, other socially relevant aspects must be considered, including the value of unlicensed spectrum or the need for harmonisation of some spectrum bands.

The valuation of spectrum being highly situational, and depending on different intrinsic and extrinsic factors, is an **increasing interest for economic approaches to spectrum management.**[35] **The first objective aims to ensure the most efficient and effective use** of available spectrum bands, and maximise the benefits for society generated by the radio spectrum.[36] A second objective is represented by **resource rent capture,** where the rent is defined and quantified as the price that a

[32] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 28-30. See Sub-chapter 5.2.
[33] C. Henry. 2017. "FCC gets five new applications for non-geostationary satellite constellations". SpaceNews (Link).
P. De Selding. 2022. "ITU approves 8-month deadline extension for OneWeb". Space Intel report (Link).
[34] ITU. 2014. "Economic aspects of spectrum management". (Link) at 31.
[35] Present and following considerations mainly derived from ITU "Economic aspects of spectrum management". (Link).
[36] ITU. 2014. "Economic aspects of spectrum management". ITU (Link) at 16.

resource would bring in an open market. Auction mechanisms hold significant potential for an accurate reflection on the value of spectrum but need to be combined with active competition policies and limits on the purchasable spectrum. Moreover, needs of non-commercial users such as radio astronomers must be considered.

To conclude, **there is a large relation between spectrum, value, and use**. Efficient spectrum use and economic return seem to be the mainstream parameters to determine the current value of a spectrum band. Nonetheless, the value of the spectrum used for public services should be considered, as well as the value of unlicensed spectrum. An assessment on spectrum value is strictly correlated to additional policy factors, including **sovereignty aspects, geopolitical issues, and its dependency from regional or national industrial policies**. Having a clear understanding of how the value of spectrum is changing is crucial for regulators when relocating spectrum with the best overall outcomes.

Relocation of the C band in the U.S – A Case Study

A clear sign of how spectrum value is changing due to new demand and use is represented by the relocation of spectrum bands for the delivery of new services, which are necessary despite the increasing optimisation of spectrum usage (e.g., frequency band sharing). **The drive for high-speed connectivity**, embodied especially in the roll-out of terrestrial 5G networks, **has increased the demand for spectrum rights**. This demand has also grown in frequencies long serving the satellite community, such as the C band in 3.7-4.2 GHz range, leading in 2019 and 2020 to the most prominent C band clearance from satellite to mobile 5G played out in the U.S. Traditionally, the C band has been used by **Fixed-satellite service (FSS)** operators such as Intelsat, SES or Eutelsat, until ITU allocated this band for 5G mobile services during the WRC-15, with limited protection for FSS operators. Essentially, the intrinsic physics of the C band make it particularly suitable for the delivery of 5G due to the balance between coverage and high throughput.

Following the WRC-15 and WRC-19, the **need to relocate part of the C band for 5G services has grown**. In 2020, the U.S FCC adopted rules to free 280 MHz (plus 20 MHz guard band) of mid-band spectrum with the transition of existing services out of the 3.7-4.0 GHz band into the upper portion of the band (4.0-4.2 GHz) with a 2025 deadline. It also offered the option (with additional incentives) to accelerate the process in two earlier phases: the lower 120 MHz to be cleared by 2021 and the upper 180 MHz by 2023.[37] The FCC auctioned the 280 MHz for 5G in December 2020, with $78 billion in revenues, a record compared to previous FCC auctions.[38] The FCC agreed with the largest satellite Alliance (i.e., C band Alliance), led by Intelsat, on the full compensation of their cost of exiting the band, including the construction of new satellites (estimated $3.5-$5.2 billion for procurement of new satellites, TT&C and gateway consolidation, technology upgrades), and approved up to $9.7 billion in incentives for the quicker migration.

Intelsat will receive the final payment of about $4.9 billion and SES $3.97 billion in total proceeds, having managed to meet FCC's anticipated 2023 deadline; the two companies have already unlocked more than $2 billion together by meeting the first-phase milestone in 2021, and they both successfully met the milestone ahead of schedule in August 2023. Eutelsat and Telesat respectively announced they expect to receive $382 million by the end of 2023 for its C-band clearing, following $125 million in interim proceeds; and $260 million for the last phase of its C-band clearing efforts, following an $85 million interim payment.

[37] FCC. 2020. "FCC 20-2". Federal Communications Commission (Link).
[38] J. Manner. 2022. Spectrum Wars. and K. Hill. 2021. "Auction slows as it surpasses $80 billion". RCR Wireless (Link).

4 Regulating spectrum: the ITU and national system

A clear and certain, yet adaptive, **regulatory framework is key for the radiofrequency spectrum** to be used in an effective and efficient way, ensuring operations free from harmful interference. This can be translated onto a highly competitive and complex system addressed through **radio spectrum management.** The latter can be defined as:

> "*the process of regulating the use of radio frequencies to promote efficient use and gain a net social benefit.*"[39]

Radio spectrum management activities integrate administrative and technical procedures with the **aim to maximise the utilisation of radiofrequency bands**, while avoiding harmful interference. With the same objective, **radio frequency management procedures take place both at the national and international level**. At the international level, several national spectrum administrations and supranational organisations are directly or indirectly involved in spectrum management, including ITU, International Civil Aviation Organisation (ICAO), and the World Meteorological Organisation (WMO).

The International Telecommunication Union system

The extensive and complex **international regulatory regime for telecommunications has been established through the ITU**, one of the oldest specialised agencies of the UN, devoted to Information and Communication Technologies (ICTs).[40] ITU's legal framework does not have the character of a self-contained regime and thus "*the rules on distribution of orbital slots and associated radio frequencies should be interpreted and applied in close connection with the general principles of space law, which is in turn part of international law at large*."[41]

ITU works through three main "Sectors":

Figure 4: Three ITU Sectors

The treaty-based agency manages the finite radio spectrum worldwide through continual consultation, cooperation, and coordination, and operates through its **ITU- Radiocommunication Sector (ITU-R) and Radiocommunication Bureau (BR).**

ITU's 193 Members States act together as global spectrum coordinators, after consultation of their national stakeholders (i.e., radio frequency users composed of government organisations, the communication industry, academia, researchers, and the public). Their rights and obligations are defined in **the ITU CC and complemented by the Radio Regulations (RR).** Radio frequencies and any associated orbits are regulated with the intent to avoid harmful interference under Article 45 of the ITU Constitution. In addition, Article 44 stated that "*in using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit,* **are limited natural resources** *and that they must be* **used rationally, efficiently and economically,** *(…) so that countries or groups of countries may have equitable access to those orbits and frequencies.*"

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[39] C. Doyle, et al. 2007. Essentials of modern spectrum management. Cambridge: Cambridge University Press.
[40] A. Froehlich. 2021. Legal Aspects Around Satellite Constellations. Basel: Springer Nature Switzerland.
[41] S. Marchisio. 2014. "The ITU Regulatory System: A Self-Contained Regime or a Part of International Law?". IRIS (Link).

The ITU RR are a binding international treaty modifies and updated at the ITU-R World Radiocommunication Conference (WRC) every three to four years to consider the technical developments and relevant changes in spectrum use. It governs the use of radiofrequencies and specifies the conditions for the international arrangements. It contains allocations, plans, and procedures (table of frequency allocation to the services, regulatory provisions for spectrum utilisation). RR are supplemented by Rules of Procedures (RoP), which describes specific interpretation and application of the articles of the RR. Because of their binding nature for ITU Members, states must domestically apply their provisions, adopting adequate national laws and regulations, in addition to special bilateral or multilateral arrangements. Concrete regulatory arrangements and enforceability remain with states. In particular, the RR not only provides the rules to be applied to spectrum use, but also establishes rights and obligations resulting from that use.

While the harmonisation of allocation worldwide remains the aim of the ITU, **the organisation manages the radio spectrum by dividing the world into three ITU regions**, with each region having potentially its own set of **radio frequency allocations**. This means that the radio spectrum, namely the portion of the electromagnetic spectrum ranging from 9 kHz to 300 GHz, is segmented into several bands and allocated to over 40 different types of terrestrial or space telecommunication or radio astronomy services.[42]

Figure 5: Frequency Distribution

As of today, **the ITU RR have allocated up to the 275 GHz band so far, reserving possibility to address up to 3,000 GHz**. Frequency bands are either exclusively allocated to a single radiocommunication service, or to more than one through a shared frequency allocation. These services are defined as primary or secondary, with the latter prevented from causing harmful interference to the former, or claiming protection from it. The outcomes of the agreed frequency allocations are included in **ITU RR Article 5, which defines the (international) Table of Frequency Allocations (TFA).** The TFA is based on a block allocation method (i.e., a discrete portion of the spectrum is allocated to the different services), including footnotes providing further specifications on how the bands are to be assigned or used. [43]

The TFA is part of RR and as such is an international treaty to which National Administrations shall be in conformity with. Countries rely on the TFA and comply with the condition that regulates the use of frequencies in the allocated bands (e.g., compliance with allotment plan; requirement for coordination procedure; mandatory notification). While changes made to the TFA during the WRC are frequently self-executing upon ratification of the WRC Final Acts, **countries may deviate from agreed international allocations with the use of footnotes to the TFA or pursuant to Article 4.4 of the RR (non-conforming use)**, under the constraining rule that this does not cause harmful interference to, and not claim protection from harmful interference to services in other countries and stop operation immediately if a protection of such frequency band is required.[44]

In line with the national spectrum management policy of the country, **policy and technical considerations for the implementation of WRC decisions are usually taken care though public**

[42] ITU. 2007. "West African Common Market Project". ITU (Link).
[43] GSMA. 2017. "The spectrum policy dictionary". GSMA (Link).
[44] See non-conforming assignment (No.8.4) in accordance with No. 4.4. J. Manner. 2022. Spectrum Wars: The Rise of 5G and Beyond. Boston: Artech House. p. 64. See also ITU. 2020. "Spectrum Management". Digital Regulation Platform (Link): 11.

consultation (e.g., the U.S) or rulemaking. Therefore, several national spectrum management practices are observed, while some basic, common processes are recognised. Furthermore, countries can nationally add limitations in terms of who can use specific frequencies (e.g., it is the case of frequencies that are assigned to space services internationally, but that nationally are open to use for Military/Government operators – but only within the boundaries of space services).

Member States maintain sovereignty over the use of radio frequencies within their territories. In line with their national spectrum management policies, and in compliance with the (international) TFA, they establish their national TFA. Upon the request of stations operators, the spectrum management authority of each country assigns the frequency to a station of the given radiocommunication service, issuing the related licence and (potentially) determining the related fees (See Thematic Box: "Frequency Assignment & Licensing").

For satellite networks, **ITU filing system operates out of the Space Planned bands on the principle of "First Come First Served" (FCFS)/efficient orbit/spectrum use** and interference-free operation satisfying actual requirements, based on the right and obligation of the "coordination before use" approach for non-planned services, which includes a two or three-step procedures depending on the type of network published, in the BR's International Frequency Information Circular - BR IFIC (Space):

- **Advance Publication Information (API) procedure** for some non-GSO networks.
- **Coordination procedures (CR),** with ITU technical and regulatory examinations to identify need of coordination followed by coordination with relevant administrators for GSO and some non-GSO networks or adjustment of parameters.[45]

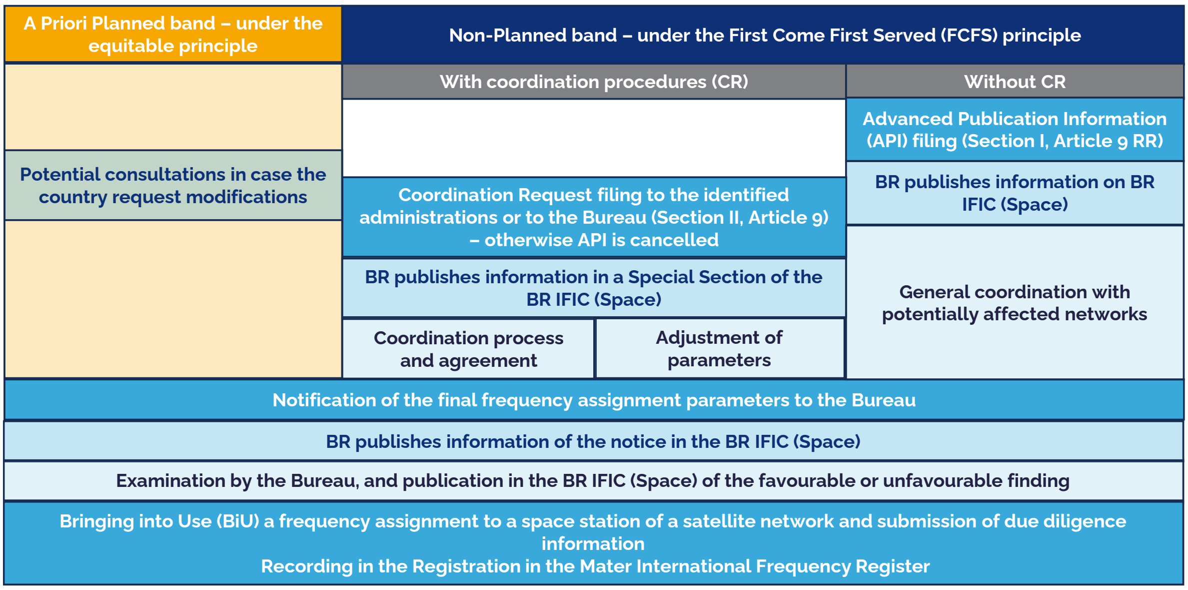

Figure 6: Spectrum Management procedures for planned and non-planned space services

To give (more) priority to the **principle of equitable access to orbit/spectrum resources for future use**, ***a priori* planning approach** allows Member States to have access to a predetermined share of the frequency spectrum in part of BSS and FSS from an associated GSO position on their territory with the overarching goal to optimise the development and equitable sharing of the GEO belt and address the problems of its limitedness, scarcity and saturation.[46]

[45] Sec. I of No. 9, RR-2020 (vol. I) and Sec. II of No. 9, RR-2020 (vol. I).
[46] Appendix 30, 30A, and 30B. See R. Jakhu. 1982. "The Legal Status of the Geostationary Orbit". Annals of Air and Space Law 7: 344. F. Lyall. 1994. "The International Telecommunication Union and Development". Journal of Space Law 22: 24.

Even though not all Plan assignments are currently in operation, they are protected from harmful interference from other networks based on the Plan characteristics.

BSS Plan – Appendices 30/30A	FSS Plan – Appendix 30B
Plans separated by Regions	Worldwide plan
Assignment plans	Allotment plans (conversion to assignments before use)
Shared with other space services in other Regions	No other space service allocated
List for R1&3 only	List for all 3 Regions
Cluster concept in Region 2 plan	Protection based on grid points in service areas for downlinks

Table 1: BSS and FSS Plan features (Credit: ITU)

Finally, the international recognition of the rights to use the spectrum from an orbit free from harmful signal interference occurs by recording frequency assignments from orbital location, in the **Master International Frequency Register (Master Register).** The time to fulfil ITU procedures is limited to keep the Master Register close to operational satellites. The time between the API/CR reception by the BR and the **complete Bring into Use (BiU)** is a maximum of 7-year, and 8 years in the Planned bands from the date of receipt of Article 4 (Part A) submissions of Appendices30/30A of RR or Article 6 (A6A) submissions of Appendix 30B of RR.

Frequency Assignment methods & Licensing

Frequency assignment has the overarching objective to provide applicants with a band that allows the best performance of the proposed activity, while at the same time ensuring that future applicants can also be accommodated in a part of the spectrum. **The completion of the assignment process by national authorities most often results in a licence**, with rare exceptions. Indeed, ITU RR No. 18.1 states that "*no transmitting station may be established or operated by a private person or any enterprise without a license issued in an appropriate form* [.]," unless operations under non-interference basis are allowed by the government.

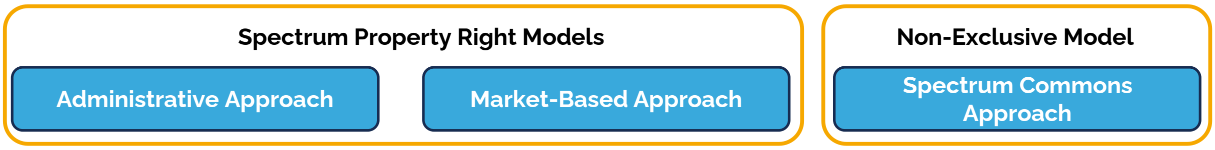

Figure 7: Spectrum Assignments Methods

Focusing on the administrative approach, the licence (also including "permits" and "authorisations", considered as licences even if with different legal authority) is the "traditional approach" to manage the use of the radio spectrum. It implies a regulator choosing the future occupant of a specific band and determining its assigned frequencies or assigning it on a *first come first served* basis.[47] This aims to create constraints for each radio station, thus conserving the limited spectrum resource for the public interest. Licence mechanisms have been defined as resulting in **"spectrum property rights" or "spectrum ownership" models** and represents the spectrum management scheme most frequently used over the past 100 years.[48]

It is an approach implying procedures used in the case of mutually exclusive spectrum requests and can be categorised as non-market-based assignment approaches, namely comparative processes and lotteries (the administrative approach). [49] In this context, spectrum can also be awarded through the so-called **"beauty contest"**, a tendering process involving the comparison of different potential users based on the identified criteria. An example in the space

[47] According to the definition of ITU. 2015. "Handbook on National Spectrum Management". (Link): 90.
[48] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 123
[49] ITU. 2012. "Exploring the value and economic valuation of spectrum". Regulatory & Market Environment (Link).

domain is provided by the licensing of MSS spectrum in Europe to two "pan-European" operators within an EU-harmonised frequency band of 1,980 -2,010 MHz and 2,170 – 2,200 MHz (2 GHz). Inmarsat and EchoStar were granted licenses until mid-2027 (See Thematic Box in Chapter 6).

Regulators can also make use of a "**market-based approach"**, mainly relying on auctions. This approach uses market forces to determine the distribution of spectrum. The entities obtaining the license can then trade their spectrum rights in a secondary market, with the incentive for owners to transfer or lease unutilised bands. This solution should favour the efficient utilisation of spectrum bands. While many regulators have incorporated market forces in the assignment procedures for terrestrial services (e.g., 5G spectrum auction bids in the United States), this approach has limited implementation in the satellite radiocommunication services. This is mostly due to the complexity and cost of space systems (with most satellite MSS/FSS/BSS systems specifically built after securing spectrum), as well as the need for frequency diversity and because operators should obtain market access rights in every country they want to operate in.[50]

An additional type of assignment is represented by the **"spectrum commons approach"** (or unlicensed/license-exempt).[51] This model allows multiple users of unlicensed spectrum, relying on the fact that technological evolution would facilitate this approach. Nevertheless, apart from the example of the 2.4 GHz and 5 GHz bands for Wi-Fi, a control of basic rules to be respected by users is still needed for the model to spread. These approaches are based on the idea that as **technologies advance, devices can cooperate and coexist, avoiding interference, leading to less scarcity of spectrum resources** (further analysis of such an approach is included in Chapter 5.2).[52] The possibility for different services to coexist (especially fixed services, while mobile may require exclusive use) is also correlated with the level of knowledge and understanding of regulatory and technical constrains by spectrum regulators.

The administrations differentiate between and the model of "individual usage rights /authorisation" (either frequency blocks, transmitting stations or coordinated networks will be licenced), or a "common model" (with general licence for all applications which can cope with the predefined technical conditions).Today the general practice is still mostly an exclusive or semi-exclusive access to spectrum for satellite use, allocating the frequencies to the primary service (e.g., 5G frequencies) and then allowing secondary service operators to apply for licenses on a FCFS basis, provided they will not interfere. [53] Satellite operators mostly utilise secondary allocations as filler for their services. In addition, general licenses are commonly provided for the terminal equipment meeting certain technical requirements.

Finally, countries have financed their spectrum management programs through the allocation of a portion of the annual budget to spectrum management, based on government priorities. Nevertheless, as the state is the "owner" of the spectrum, **different types of fees can be charged to occupants**; in particular, usage fees (considering economic benefits from spectrum use by occupants), or administrative fees (to cover the cost of spectrum management activities) are worth mentioning. Additionally, revenue generated through auctions is another funding approach. While no country solely relies on auction revenues, as shown by the C band auction held by the FCC in 2020, Australia, Canada and the UK also charge government entities for their spectrum use. [54]

[50] An analysis of this procedure should be better investigated at the regional level, and it is further assessed in Chapter 6.
[51] ITU. 2020. "Spectrum Management". Digital Regulation Platform (Link): 76-77.
J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 70.
[52] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 1124, 125. p. 125.
[53] For the sake of completeness, before the advent of 5G all licenses were relying on individual usage rights.
[54] ITU. 2014. "Economic aspects of spectrum management". ITU (Link).

5 CHALLENGES TO TACKLE AT THE WRC-23 AND BEYOND

The WRC is a treaty-making conference organised by ITU that brings together Member States every three to four years and plays a key role in shaping technical and regulatory frameworks for the provision of radiocommunication services in all countries. Among other tasks, **it revises the RRs.** It also adopts technical studies and work plans for a six to ten-year cycle, spectrum allocations, satellite regulatory procedures, space plans of the radio frequency spectrum, and reviews RoP and appeals from the Radio Regulations Board (RRB). [55]

The **WRC Agenda** results from the decision made by the previous WRC. Its final version is approved by Council of the ITU.[56] **The preparatory process relies on the work of ITU-R Study Groups (SG)** responsible for assessing the technical, operational, and procedural issues of the WRC Agenda Items.[57] Each SG refers to a general radiocommunications matter and is divided in Working Parties (WP) that carry out preparatory studies to answer questions assigned to the group, relying on the expertise of over specialists worldwide.[58]

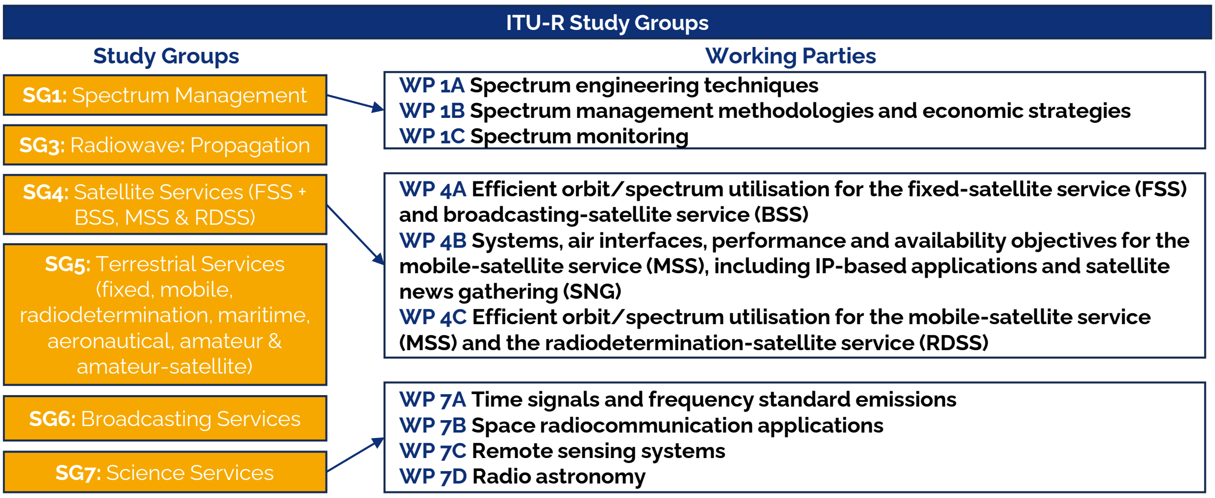

Figure 8: ITU study groups related to space (Credit: ITU, ESPI)

Preparations for the WRC include continuous work of the ITU-R SG meeting several times per year and leading to the Conference Preparatory Meetings (CPM), taking place after the WRC and six months before the next conference, as well as the work of the **ITU inter-regional workshops**. Consolidated positions along regional approaches are reached by the regional groups while each nation comes to its own conclusion regarding different Agenda Items. **Six main regional telecommunication organisations (RTOs) serve as forums for regional discussions and consensus,** including the European Conference of Postal and Telecommunications Administrations (CEPT), the Inter-American Telecommunication Commission (CITEL), and the Regional Commonwealth in the Field of Communications (RCC).

The WRC's decision-making process is based on the principle of international consensus.[59] Industry and private sector participate and contribute actively to the Study Groups, to the CPM Report and also

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[55] The ITU Radiocommunication Bureau acts as the executive arm of the RRB.
[56] The Council acts as the Union's governing body in the interval between plenipotentiary conferences.
[57] GSMA. 2017. "An Introduction to the WRC". GSMA (Link).
[58] ITU, n.d. "Radiocommunication Study Groups". ITU (Link).
[59] The Resolution ITU-R 1-8 "Working methods for the Radiocommunication Assembly, the Radiocommunication Study Groups, the Radiocommunication Advisory Group and other groups of the Radiocommunication Sector (1993-1995-1997-2000-2003-2007-20122015-2019) states: "Consistent with the United Nations practice, consensus is understood to mean the practice of adopting decisions by general agreement in the absence of any formal objection and without a vote". Additional details can be found in ITU. 2022. "The Art of Reaching Consensus". ITUWTSA-20 (Link).

participate in the WRC either as being part of Member State delegations or as a Sector Member. Sector Members can take place in the debates (with exception on future Agenda Items) but not in the decision-making process. Researcher, academia, or civil society participate in and contribute to Study Groups on emerging issues in the ICT field (serving as Study Group rapporteurs and editors) advice but cannot submit proposals or participate in negotiations and decisions. Decisions are incorporated into the RR as an amendment to (added/suppressed/modified) provisions, resolutions, and recommendations to the Radiocommunication Assembly and ITU-R SGs; they are then reflected immediately in the Final Acts before being merged in a new version of the RR in the six languages of UN. The last version of the RR adopted in 2020 reflects the decisions reached by representatives of the 163 Member States that participated in the Conference, and compiles decisions of previous conferences and the final acts of the WRC-19.

The WRC-19: Major achievements on spectrum management

In late 2019, the **WRC-19 took place in Sharm el-Sheikh, Egypt**. Among other matters, the agenda addressed the rollout of 5G mobile networks and allocated more than 17 GHz of new spectrum for cellular 5G.[60] Additionally, frequency bands were identified for High-altitude Platform Station (HAPS), which could become yet another competitor for satellites in some applications. Thanks to the work achieved by the satcom community, the spectrum allocations did not come at the cost of a drastic reduction of spectrum rights that are essential for commercial satellite operators.

Space-related decisions included:

- Regulatory arrangements facilitating the conduct of short duration satellite missions;
- Spectrum and definition of deployment milestones for non-GEO satellite constellations;
- Spectrum for Earth Stations in Motion operations (e.g., internet access on-board aircraft);
- Millimetre wave frequencies (51.4-52.4 GHz) for fixed satellite services;
- Changes of the table of frequency allocation;
- Associated task regarding the governance of spectrum resources, including adopting resolutions and recommendations.[61]

Although the WRC-19 has attempted to resolve multiple spectrum policy issues from a regulatory and policy perspective, **the deployment of satellite constellations and increased congestion on the physical and spectrum-related environment is continuing to pose several challenges**. This concerns the overarching international spectrum management system, and national legal regimes.

This year, the RA-23 conference will take place from 13 to 17 of November in the same location, and immediately preceding, the WR.[62] **The WRC-23 will be held from 20 November to 15 December 2023,** and will tackle several issues shaping the future of spectrum management for terrestrial, maritime and space services, dealing with a transition through a "*new era of space development that poses a big challenge for ITU and the international community*."[63] The 2nd session of the **Conference Preparatory Meeting (CPM)** held from 27 March to 6 April 2023 prepared the consolidated report to support ITU Member States' preparation of proposals to the WRC-23.[64]

[60] ITU. 2020. "WRC-19 identifies additional frequency bands for 5G". ITU (Link).
[61] ESPI. 2020. "ESPI brief No.37: Rethinking the assessment of the value of spectrum". ESPI (Link).
[62] ITU. 2022. "ITU-R Study Groups and the Radiocommunication Assembly". ITU (Link).
[63] See ITU WRC-23, (Link). ITUPP. 2022. "Highlights: ITU Plenipotentiary Conference 2022". ITU (Link).
[64] ITU. n.d. "Conference Preparatory Meeting (CPM)". ITU (Link).

The WRC-23 has 10 Agenda Items (AI), with 19 topics under AI 1, 11 topics under AI 7 and 4 topics under AI 9.[65]

WRC-23 Agenda Topics

- **AI 1:** Consider the requirements of existing and future services in frequency bands under consideration of ITU-R studies.
- **AI 2:** Examine revised ITU-R Recommendations and decide whether to update corresponding references in Radio Regulations.
- **AI 3:** Consider consequential changes and amendments to the Radio Regulations if necessitated by the decision of WRC-23.
- **AI 4:** Review Resolutions and Recommendations of previous conferences in accordance with Res. 95 (Rev.WRC-19)
- **AI 5:** Review the report from the Radiocommunication Assembly.
- **AI 6:** Identify items requiring urgent action from the study groups in preparation for the next WRC.
- **AI 7:** Consider a possible response to the Plenipotentiary Conference.
- **AI 8:** Take appropriate action on requests from administrations to delete their country footnotes.
- **AI 9:** Consider and approve the Report of the Director of the Radiocommunication Bureau.
- **AI 10:** Recommend the Council items to be included in the agenda for the next WRC.

Figure 9: WRC23 Agenda Items

Among others, space services-related topics include AI 1 (in particular, 1.15, 1.16, 1.17, 1.18, 1.19) and AI 7. For instance, under AI 1.17 Member States at the WRC-23 will develop the regulatory framework for **satellite-to-satellite links in the Ka band**, following the studies conducted pursuant to Resolution 773 (WRC-19). Proposals for AIs concerning similar uses of the C band are under discussion for WRC-27 Agenda.[66] AI 7 is aimed at considering possible changes, in response to Resolution 86 (Rev. Marrakesh, 2002) of the Plenipotentiary Conference, on advance publication, coordination, notification and recording procedures for frequency assignments pertaining to satellite networks. This is in accordance with Resolution 86 (Rev. WRC-07), to facilitate the rational, efficient, and economical use of radio frequencies and any associated orbits, including the GSO.

The growing need for connectivity of **earth stations in motion** (ESIM), especially in the aeronautical and maritime sectors, is at the core of the discussions regarding AI 1.15 and 1.16. Respectively, the use of a larger band for GSO ESIM connectivity will be discussed, as well as the development of technical, operational, and regulatory measures for non-GSO ESIM. Moreover, among the proposed AI to the WRC-27, additional bands for non-GSO ESIM connectivity are also being considered.[67]

Furthermore, discussion has started on the identification of new frequencies/allocations for **Lunar activities** (also considering activities already conducted under NASA´s Lunar Spectrum Framework), as well as for ISAM spacecrafts operations.

To conclude, the WRC-23 will tackle several critical issues shaping the future of spectrum management for space services, while an even broader analysis will be required in the identification of Agenda Items for the WRC-27.[68] Those may include, among others, the impact of non-GSO satellite constellation (over)filings, aspects related to harmonisation and flexibility in spectrum allocations, non-GSO post-mission disposal and the inclusion of equitability and sustainability concerns in the overall

[65] ITU. 2023. "ITU-R Preparatory Studies for WRC-23". ITU (Link).
[66] A. Marklund. 2023. "The Road to Dubai: SES Perspectives on WRC-23". SES (Link).
[67] GSOA. 2023. "GSOA WRC23 Positions". GSOA (Link).
[68] Additional details at GSOA. 2023. "GSOA WRC23 Positions". GSOA (Link).

framework. While the WRC-23 AIs can be found in Annex C, the sections below aggregate and prioritise several challenges considered relevant.

Figure 10: Conceptualisation of Space Spectrum Policy Challenges (Credit: ESPI)

5.1 Dealing with overfiling and Bring into Use rules

While allocated spectrum is arguably underutilised, **the phenomena of overfiling and the problem of reserving spectrum capacity without bringing the system into use** have been a longstanding concern for ITU. Despite efforts to control overfiling, administrators still file for satellite systems to maintain competitiveness, increasing pressure on the entire frequency band allocation system. Forty years ago, the practice, referred to as "paper satellites", started with regulatory filings sent to ITU without the intention of manufacturing and launching satellites by the filing organisation or state.[69] In one of the most referenced cases, 1990 saw the Tongan government file for sixteen GSO satellites, without an actual plan to launch them but with the intention of leasing them to other operators. While the episode did not *per se* violate any RR provision, the actions were perceived as contradicting the spirit of international law.[70]

ITU addressed the higher processing time due to overfiling in the 1990s (which had resulted in processing backlog) without harming the growing industry and the needs of sovereign states. Resolution 18 (Kyoto, Plenipotentiary Conference 1994) instructed the Director of the BR to review issues concerning satellite coordination, including concerns related to paper filings. To discourage the reservation of capacity without actual use, the WRC-1997 considered an approach where each administration would be required to provide evidence that demonstrated an intent to establish a satellite system within the regulatory procedures.[71]

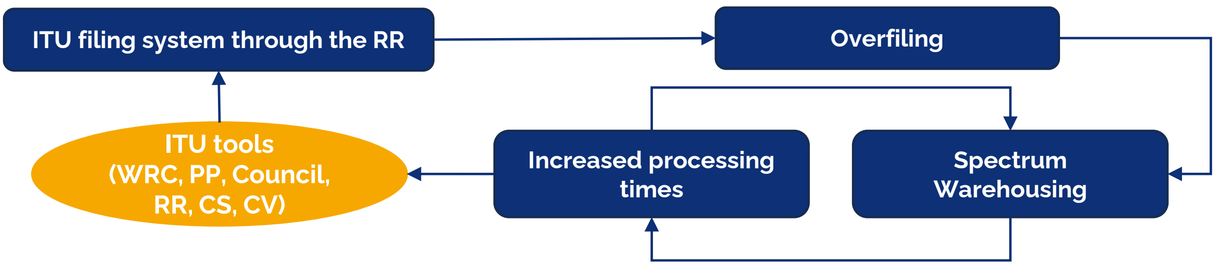

Figure 11: ITU overfiling, abuse of the BIU rules, and warehousing cycle (Credit: ITU, ESPI)

The consequences of implementing administrative due diligence procedures were considered in the WRC-2000. **Administrative due diligence (Resolution 49 to the RR, Revision WRC-19)** consists of a regular disclosure of information in the implementation of the respective satellite system within the regulatory time limits (RR No. 11.44).[72] If the complete due diligence information is not received, the network is cancelled from the Master Register or Appendices 30/30A/30B Lists or Plan and is

[69] A. Allison. 2014. The ITU and Managing Satellite Orbital and Spectrum Resources in the 21st Century. Cham: Springer. p.26.
[70] S. Aoki. 2014. "Efficient and equitable use of orbit by satellite systems". EIP (Link): 232.
[71] ITU. "Financial Diligence". ITU Plenipotentiary Conference (Link).
[72] Under RR No. 11.48 (inc. the identity of the satellite network, spacecraft manufactures, and launch service provider).

no longer considered when applying the coordination and recording procedures for other networks. On the other hand, BR examines the information for completeness and, if a notification is received before the date of BiU, the assignment is recorded provisionally in the Master Register and definitely only once the due diligence is received within the maximum time limit. The approach applies to satellite networks of FSS, MSS or BSS with frequency assignment that are subject to coordination procedure[73] and to submission for plans. [74] Besides administrative due diligence, the **financial due diligence** (discussed at the WRC-1997 as a complementary type of procedure) is aimed at ensuring users pay for the costs incurred in ITU´s satellite networking filings. The proposal came to an agreement at Council Decision 428 (1999). **ITU Council determined the cost recovery principles** and associated fees for satellite network filings, establishing a schedule of processing charges that relate to the complexity and size of filing (inc. one free entitlement a year for each member state). The WRC determines regulation covering satellite network filings, in particular, the penalty in the event of non-payment of cost recovery fee.[75]

The current practice for GSO systems for non-Plan, as defined in No. 11.44B of the ITU RR, considers a frequency assignment to fulfil the BiU rule when a satellite in GSO capable of transmitting or receiving that frequency assignment has been **deployed and maintained at the notified orbital position for a continuous period of 90 days**.[76] However, a practice to overcome the BiU rule includes moving a satellite to another orbit to avoid missing BiU deadlines, a practice that seems to be representative of 28% of registrations between 2015 and 2022 for satellites that had been BiU in other orbital slots.[77] For instance in 2012, Iran reportedly renamed operating satellites from another orbit to prevent the deletion of its Zorer-2 system from the Master Register.[78]

To deal with this practice, and improve the overall systems for the use of frequency orbit pairs in GSO, Resolution 40 (Rev. WRC-19) is tracking the satellites' bringing into use filings to identify the "hopping" phenomena.[79] The administration must specify if the station has been previously used to address the BiU requirement or resume the use of frequency assignments at a different orbital location within the 3 years before the submission of the information. If the administration has used such a station, it must also provide information on the previous orbital location, the associated satellite network(s), and the date when the station was no longer maintained at the previous location within the same three-year period. This information must be submitted within 30 days of notification from the BR. Otherwise, the BR will consider that the frequency assignment was not BiU.[80]

Furthermore, **with the surge of large non-GSO satellite constellations, the dynamics of overfiling and warehousing changed, posing additional challenges on the filing procedure,** and creating a sense of urgency in enhancing ITU and national frameworks. Indeed, this entailed moving from filing confirmed BiU when a single satellite was BiU, to a system enabling a single filing for multiple satellites. It raised concerns about coping with the BiU process – in addition to the long-standing concerns related to a congestion-prone space environment.

[73] Under Nos. 9.7 (GSO-GSO), 9.11 (terrestrial services - 9.12, 9.12A) and 9.13 and Resolution 33 in ITU. 2012. "Article 11: Notification and recording of frequency assignments". ITU (Link).
[74] In particular, any submission under Article 4 of Appendices 30 and 30A (Volume II) and any submission of information under Article 6 of Appendix30B (FSS plans), with the exception of submission of new MSs seeking the acquisition of their respective national allotments for inclusion in the Appendix 30B under Article 4 of Appendices 30 and 30A, Volume II.
[75] ITU, "Cost recovery" (Link). See Council Decision 482 and RR No. 9.38.1.
[76] J. Wheeler. 2023. "The Space Law Review: ITU and Access to Spectrum". The Law Reviews (Link).
[77] S. Aoki. 2014. "Efficient and equitable use of orbit by satellite systems". EIP (Link): 230.
P. De Selding. 2023. "28% of GEO satellites launched since 2015 used to register networks at other orbitals slots". SIR (Link).
[78] S. Aoki. 2014. "Efficient and equitable use of orbit by satellite systems". EIP (Link): 229-246.
[79] ITU. 2019. "WRC 2019 Final Acts". ITU Publications (Link).
[80] WRC. 2019. "Resolution 40 (REV.WRC-19)". ITU (Link).

ITU made some progress in addressing these issues at the WRC-15 and the WRC-19. Firstly, ITU-R was invited to examine provisions requiring additional milestones for deployment of the complete constellation beyond standard notification and the BiU procedure at the WRC-15 to prevent the risk of speculative filings and spectrum warehousing and avoid administrations blocking spectrum for orbits for others. The ITU-R BR practice on non-GSO satellite systems in the FSS, MSS and BSS were reflected in the RR No. 11.44C. The WRC-19 (AI 7.A) tackled additional rules to prevent orbit and spectrum reservation without actual use for non-GSO systems through a **milestone-based approach for frequency assignments.** Under RR NO 11.44C, a frequency assignment to satellites in any non-GSO system has completed the BiU requirement when one satellite with the capability of transmitting or receiving that frequency assignment is deployed and "maintained on one of the orbital plane(s) for a continuous period of 90 days, irrespective of the notified number of orbital planes and satellites per orbital plane in the network". To address issues posed by large constellations, in compliance with Resolution 35 (WRC-19), non-GSO systems in specific frequency bands and services must deploy a certain percentage of their constellation in specific timeframes. Within two years, they must deploy 10% of their constellations, 50% in five years, and complete the deployment in seven years.[81] This milestone-based approach increasingly ensured that the MIFR accurately reflects the actual deployment of non-GSO satellite systems and services.[82]

Milestone based approach – Resolution 35 (WRC-19)

All Non-GSO satellite systems in some bands and services, ADM should provide the respective deployment information by the following dates:

Initial deployment information
- **7-year limit + 30 days**

3 Milestones
- **M1: 7-year limit + 2 years + 30 days: 10%**
- **M2: 7-year limit + 5 years + 30 days: 50%**
- **M3: 7-year limit + 7 years + 30 days: 100%**

ADM to inform whether any of the satellites have been used for other systems

Failure to meet a milestone requirement:
ADM must submit a Modification to reduce proportionately the number of satellites in the constellation

Failure to submit modification:
Only satellites previously confirmed as deployed will be kept, and frequency assignments will no longer be taken into consideration

Figure 12: Milestone based approach (Credit: ESPI; ITU)

The focus of the WRC-23 AI 7, Topic B is addressing **consequences of failures and measures of enforceability for the post-milestone procedure**. Key considerations include determining appropriate actions if a constellation fails to meet the milestones or falls below 95% of its completion, or if it has completed the milestone process and subsequently experiences a reduction in the number of satellites deployed. Proposed options could be to extend the allowed data range to three years, adjust constellation size or frequency assignment based on the actual deployment, incorporate additional milestones into the BiU procedure, or more generally, address cases on an *ad hoc* basis before the RRB.[83] For instance, Telesat's LightSpeed constellation deployment was

[81] WRC. 2019. "Resolution 35 (WRC-19)". ITU (Link).
[82] ITU. 2019. "CMP-19-2 Report to WRC-19". ITU (Link): AI 7(A)
[83] R. Pritchard-Kelly. 2023. "WRC-23 on the Horizon". Air & Space Law 48: 183

not able to meet regulatory milestones under the spectrum authorisation.[84] Resolution 35 (WRC-19, Resolve 12) allows for several milestones to be ignored under certain conditions, including the submission of a written report indicating efforts made, and proof of a binding agreement for manufacturing and launch. More recently, ITU RRB has granted a waiver to Rivada Space Networks for the 10% milestone for its non-GSO constellation in July 2023.[85]

To conclude, companies such as SpaceX, OneWeb, E-Space, China SatNet and Amazon aim to launch constellations of up to hundreds of thousands of satellites. In 2021, the government of Rwanda made one notable filing with ITU. Their proposal included two constellations comprising a total of 327.230 satellites. These extreme filings are criticised by some industry representatives and analysts, that question their economic underpinning, the realistic manufacturing/launching plan and consider systems already in operation exceed projected demand.[86] Varying opinions on how to address these difficulties have been voiced, with some calling for a complete overhaul of the regulatory framework, while others advocating for incremental changes at each coming WRCs.[87] Critics also attributed the surge in filings to the absence of penalties for inappropriate or nonconforming behaviour. However, ITU is not a body for "judgment" where actors should apply the rules as a result of their agreement with it.

5.2 Maximising the use of spectrum across applications

In recent years, the needs of spectrum users have increased and evolved. In particular, there are requests for **greater spectrum capacity access, as well as a more efficient utilisation of spectrum resources**. Spectrum administrators must accommodate the increasing demand for faster broadband services, mobile data traffic and wireless access systems (including Wi-Fi networks), facilitate sharing with incumbent users, and develop new approaches to coordinate sharing among non-GSO systems. The situation is exacerbated by the appetite of terrestrial mobile phone operators for more spectrum (especially in C band and Ku/Ka band).

New technologies have been developed to enhance the efficient use of spectrum by current and future users. These include the use of spot beams for transponders or cognitive technologies. Technology advancement has also played a significant role in creating solutions to open higher frequency bands (e.g., millimetre-wave frequency band) to more intensive use.

However, the goal to satisfy greater demand for bandwidth can only be achieved by finding the right balance between innovative technologies and regulations to better deal with spectrum efficiency. New technologies and use cases are pressuring **regulators to implement innovative approaches, methods, and solutions to better (and more efficiently) use the radio spectrum resource and enhance the spectrum management regime**. This includes exploring relocation processes (also through incentives for incumbents) (e.g., U.S C band relocation, See Thematic Box in Chapter Three) and curtailing incumbent uses; as well as the development of tools and methodologies for spectrum sharing between technical-compatible services. These aspects are of particular importance within the context of **national assignment processes implemented by domestic spectrum management**, including not only **spectrum property right models** (exclusive licensing and potential trades in second markets) but also **non-exclusive models** such as

[84] Megaconstellations. 2023. "Tweet posted Mar 29, 2023". Twitter (Link).
[85] R. Jewett. "ITU Waives Rivada Constellation Deadline". Via Satellite (Link)
[86] J. Foust. 2021. "Satellite operators criticize "extreme" megaconstellation filings". SpaceNews (Link).
[87] A. Allison. 2014. The ITU and Managing Satellite Orbital and Spectrum Resources in the 21st Century. Springer: NY. p. 29.

(unlicensed) "spectrum commons" approaches (multiple users on nonexclusive basis).[88] Other types of sharing regimes such as the sharing of spectrum between FSS GSO satellite networks or with hybrid models or networks are also considered.

As a premise, while the possibility for different services to coexist is generally high (even though subjects to technical features, e.g., with fixed services being more suitable for bands sharing than mobile ones), the use of sharing practices is also related to the knowledge and understanding of these practices, as well as their constrains by regulators. Indeed, technical solutions are sometimes not exploited because of commercial or bureaucratic reasonings.

Focusing on the "**spectrum commons approach**", this refers to the establishment of bands for unlicensed devices, so long these devices respect specific parameters (e.g., low power of transmission, low duty cycle, etc.). An example of these models is represented by the use of unlicensed or license-exempt frequency bands, such as the 2.4 GHz and 5 GHz bands, for Wi-Fi. Different views around this approach are shared within ITU, and in regulatory proceedings at both national and regional level. Major proponents of these models include influential Silicon Valley companies like Microsoft and Intel. Another example is illustrated by the **dynamic spectrum access (DSA)-enabled devices** that allow multiple radio services or spectrum users to operate simultaneously without causing harmful interference. This approach does not foresee specific allocations: apparatuses would be functioning having access to a big chunk of spectrum via Cognitive Radios or Clearinghouses (or both).[89] This enhances communication capacity compared to static spectrum access practices, increasing spectrum efficiency and utilisation.[90] DSA are already being implemented by some governments to enhance spectrum utilisation, particularly in underutilised bands. One example is the U.S FCC Citizen's Band Radio Service (CBRS) regulatory regime in the 3.5 GHz band, which employs DSA to facilitate sharing between licensed and unlicensed mobile devices. Commercial communications, fixed satellites, and U.S military radars also share parts of the C band in this model. While still at its early stage of exploitation, it could play a vital role in dealing with the increasing congestion of the space and spectrum environment, resulting promising for spectrum mangers.

Additional approaches to make more spectrum available in the long run include **novel spectrum auction designs** (e.g., incentive-based auctions), licences which include **"use it or lose it" processes**, milestones with more stringent build out conditions/requirements, or the reduction of guard bands in international and domestic allocations (whenever technological advancement allows for it).[91]

Regulators enable incumbent users the right to share their spectrum through commercial agreements, leaving the requirements to coordinate their spectrum per their filing obligations in a operator-to-operator level. Coordinating spectrum sharing among non-GSO satellite operators plays a crucial role in ensuring fair spectrum allocation, and enabling the deployment of next-generation systems. Recently, OneWeb and SpaceX reached an agreement on a spectrum coordination plan (valid over the U.S territory), possibly driven by the need for launch capacity on

[88] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 124 Analysis of these approaches has been included in Chapter 4.
[89] A Cognitive Radio is a device capable of knowing its location and of sensing (or knowing via real time databases) who is using what frequency in its surroundings (thus picking a frequency, channel, power of transmission, modulation and so on) to avoid interfering/being interfered with, in an automatic, real-time way.
[90] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 127.
[91] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p.145. See also Chapter 6.

OneWeb's side.[92] Their connected Ku bands will provide 2nd-generation networks for their broadband customers.

In certain cases, regulators have imposed the requirement to share a given amount of spectrum amongst a certain number of operators to ensure competitive and equitable access to spectrum.[93] In other cases, administrations are also implementing rules requiring demonstration of the ability to coordinate with incumbent operators prior to emitting licensure, as a pre-emptive measure. In addition, regulators have also enabled incumbent users to the right to share their spectrum by awarding usage rights in areas or times when the incumbents are not utilising it. If sharing is not voluntary, secondary usage rights should be outlined in the incumbent's primary spectrum license, allowing them to plan accordingly. Incumbent license holders should also be compensated for sharing their spectrum, considering the opportunity costs involved.[94]

Spectrum efficiency can also be enhanced using hybrid models, because users are notably interested in the quality of the service, notwithstanding the technology at its basis. Services intermittently access the same or ideally adjacent frequencies (to save on hardware), and ensure continuous delivery of RF service to a user, as conditions surrounding that user change and make it easier for a single radiocommunication service to operate versus the other. An example is that of D2D, which is usually combined with other communication technologies to deliver a fully-fledged solution. This includes the combination of MSS with terrestrial or complementary ground components, especially in the S bands 1980-2025 MHz and 2170-2200 MHz. Alternatively, network and end user services (and equipment) that combine multiple GSO satellite networks, or terrestrial and wireless with non-GSO satellite network, have been explored. Enhanced spectrum sharing and maximising existing bands for efficient 6G networks will be even more relevant. Unlike 5G, which already encompasses all fixed and mobile terrestrial and satellite technologies, 6G will require even greater capacity and higher speed to serve advanced applications which will connect humans to a variety of objects.[95] New techniques, such as Artificial Intelligence algorithms, can improve spectrum sharing, but it requires planning for THz frequency bands to enhance spectrum utilisation efficiency.[96]

Hybrid technologies, including networks and end users' services as well as network of network systems, represent a clear example of **areas where the role of spectrum harmonisation is crucial, especially in enabling the seamless interoperability of these systems**. Radio-based communication technologies and networks rely on spectrum harmonisation, either at regional or international level. This ensures a level of synergies and overall efficiency in its allocation and utilisation, while also guaranteeing regulatory certainty. Harmonisation is particularly critical in the satellite industry, where "*they could benefit from the ability to use the same equipment with the same frequency bands across the globe*."[97] This harmonisation is crucial for fixed, mobile, satellite, and broadcasting industries as it enables economies of scale, connectivity, and interoperability. Harmonisation efforts are pursued within ITU, with the WRC-23 increasing its efforts to achieve and encourage global regional harmonisation, especially beyond the WRC.

[92] M. Khan. 2023. "Dish Network, Environmental Group Sue to Stop SpaceX's Second-Gen 13 Starlink". PC (Link).
[93] FCC. 1994. "Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile Satellite Service in the 1610-1626.5/2483.5-2500 MHz Frequency Bands. 9 FCC Red 5936". FCC (Link)
[94] A. Pourmoghadas et al. 2016. "On the Spectral Coexistence of GSO and non-GSO FSS Systems: Power Control Mechanisms and a Methodology for Inter-site Distance Determination". Int. J. Satell. Commun (Link): 4-5.
[95] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 22, 169,170.
[96] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 179-180.
[97] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 73

Concerns around non-GSO orbital tolerance

Orbital tolerance concerns the acceptable (and therefore allowed) deviation of operational orbits of satellites from the altitude listed in their ITU filings. This discussion, which relates to the physical question on **how close operationalised LEO orbits may be to each other**, is becoming of higher importance as satellite constellations require multiple fleets of satellites to be flown at slightly different orbits to minimise collision risks. Therefore, many operators launch different batches of satellites slightly above or below the altitude "notified" to ITU, thus making coordination more complex.[98]

In this context, it should be considered that non-GSO satellites equipped with automatic collision avoidance systems might systematically violate potential tolerance areas; and they might create a de-facto no-access/uncoordinated orbital shell if the collision avoidance capability is factored in the tolerance area. Also, smallsats are often built and filed for not really knowing which launch vehicle will deliver them to orbit – as the filing often precedes launch booking –, increasing the risk for inaccuracy in the (ITU) filings for what concerns orbital parameters. They are barely equipped with propulsion and often rely entirely on their launcher to establish their final orbit.[99]

As no rules on orbital tolerance are currently in place, ITU study groups are discussing methods with which to outline acceptable deviation ("tolerance"), as well as whether deviation should be measured by an absolute number or a percentage of the baseline altitude. The WRC-23 Agenda Item 7 topic A will compel Member States to conclude and clarify how decisions on orbital tolerance play into regional efforts in Space Traffic Management. Ultimately, these decisions will **strengthen the commercial vitality of the built-out milestones**.

5.3 Harmonising spectrum management

Spectrum harmonisation and spectrum sharing play a crucial role in ensuring the efficient use of spectrum **at the international, as well as at the regional level, while also** facilitating sustained growth, innovative service and fostering economies of scale.[100] **Spectrum harmonisation in the satellite industry is enhanced through the increased use of standards**. Standardisation and regulatory harmonisation are necessary to facilitate the rapid implementation of evolving radio technologies such as Wi-Fi, the 4G and 5G ecosystems, and beyond. The satellite industry has worked with several standardisation bodies on improving the performance of both GSO and non-GSO networks.

The critical role played by the satellite industry in the telecommunication sector, and the rising need to better integrate space and terrestrial networks effectively, are demonstrated by the **recent inclusion of non-terrestrial networks in standardisation documents for standards bodies such as the 3rd Generation Partnership Project (3GPP) and ITU.** [101] The 3GPP is a project established in 1998 by multiple telecommunications standard development organisations to provide a complete system description for mobile telecommunications through officially published releases. Initially focused on 3G, the partnership's scope has expanded to include technical standards for 4G and 5G.

[98] R. Pritchard-Kelly. 2023. "WRC-23 on the Horizon". Air & Space Law 48, Special Issue.
[99] Parallel studies on the GEO orbit show the significant discrepancy of most satellites from their prescribed orbital longitude as seen in Roberts & Linares. 2022. "A Survey of ITU Space Station Applications in the GEO". AMOS (Link).
[100] Policy Tracker. 2023. "How does EU spectrum policy work?" Policy Tracker (Link). See also J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 159.
[101] ITU. 2015. "Handbook on National Spectrum Management". ITU (Link).

Actors and stakeholders involved in the cooperation include telecommunications standard development organisations, ITU, and other relevant industry entities.

Within this framework, **the approval of normative activities on non-terrestrial networks in 3GPP Release 17** has generated significant interest. Release 17 enables NR-based satellite access for global service continuity. The standard aims to define "5G for space: the NR NTN standard" and is further supplemented by the ITU WP4B's efforts to develop standards for the satellite component of **International Mobile Telecommunications (IMT) beyond 2022.** It supports satellite access for IoT use cases, including satellites in 3GPP specifications, and it will drive global access to 5G and stimulate satellite industry growth.[102]

Focusing on IMT, through international deliberations involving government and industry radiocommunication experts, ITU has established global technology standards for the last three generations of mobile broadband: IMT-2000 (3G), IMT-Advanced (4G), and IMT-2020 (5G). These standards enable harmonisation, implementation, and best practices for IMT requirements and its radio interface through regulations, global standards, and core network standards.[103] In addition, ITU-R Recommendations have been developed to provide detailed technical specifications for the terrestrial and satellite radio interfaces of IMT, thus enabling ubiquitous coverage for IMT.[104]

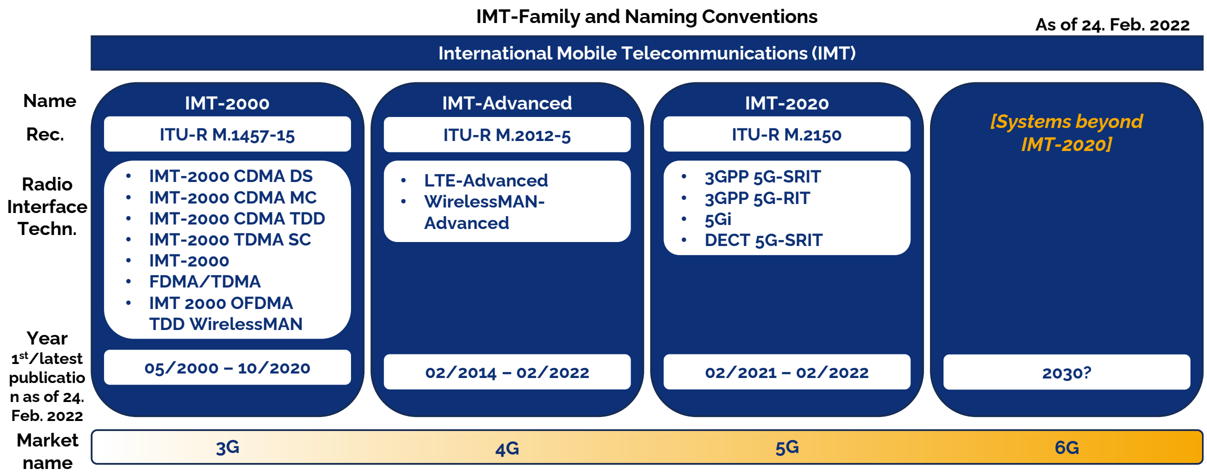

Figure 13: IMT Naming Conventions (Credit: ITU; ESPI)

Several satellite operators have urged countries to make better use of the already identified IMT and to prioritise spectrum optimisation or spectrum refarming over the identification of new spectrum.[105] This is particularly relevant in the context of Agenda Items 1.2, 1.3, 10, as well as in the identification of AI for WR-27 (See Thematic Box:"WRC-23 Agenda Items related to IMT 17 GHz").

In line with the intertwined nature of standards and spectrum allocation process, **standard-setting and spectrum management processes are strengthening their relations**, with governments increasingly considering standard bodies and involving themselves in the establishment of standards alongside private actors. On their end, standard bodies are getting closer to space (e.g., ISO getting the qualification of COPUOS Observer) or witnessing the participation of space entities in their framework (e.g., 3GPP). In a few circumstances, these bodies also liaise with ITU-R Study groups to obtain and provide relevant information, so as to better inform their internal work. The ITU-R Study Groups and ITU-T Study Groups conduct extensive studies and discussions involving

[102] M. Jaffar & N. Chuberre. 2022. "NTN & Satellite in Rel-17 & 18". 3GPP (Link).
[103] ITU. n.d. "ITU-R SECTOR ITU-R FAQ on IMT". ITU (Link).
[104] ITU. 2022. "Handbook on International Mobile Telecommunications (IMT)". ITU Publications (Link).
[105] A. Marklund. 2023. "The Road to Dubai: SES Perspectives on WRC-23". SES (Link).

stakeholders from governments, regulators, industry, and academia to drive these developments. On another side, the limited number of existing ground segment service providers (e.g., KSAT, Viasat, SSC, Leaf Space, ATLAS, Contec, AWS GS) compared to the plethora of operators, is *de facto* informing the market around the same standardised frequencies, procedural practices, hardware and protocols suggested by the firsts. Finally, the availability but also reduced cost of the equipment is significantly favoured by the presence of standards. Overall, **the role of this dialogue is an imperative for the success of spectrum's standard and management organisations.**

In parallel to this standardisation process, a twofold trend is witnessed. Companies such as SpaceX are verticalising their solutions, building their user terminals themselves, while others partner to provide Direct-to-Handset or Direct-to-Device solutions (Apple & Globalstar, Huawei & Beidou, Iridium & Qualcomm), thus developing parallel solutions with different industrial standards.

WRC-23 Agenda Items related to IMT 17 GHz

7-24 GHz is a congested band range, being allocated to 16 radio services. It is heavily populated by satellite, with satellite operator struggles to accommodate the growing services demand in core FSS & MSS & BSS bands operating in these ranges. **A large portion of spectrum has been identified for IMT in previous WRCs.** For instance, WRC-19 identified a total of 17.25 GHz bandwidth for IMT above 24 GHz with only a limited number of countries having used it for 5G as of today. However, in addition to spectrum identified for IMT at WRC-19, the IMT industry is pushing to obtain access to additional global harmonised mid-band spectrum in the band between 7 and 24 GHz that could be potentially identified for IMT as part of AI 10 at the WRC-23.[106]

Further harmonisation of spectrum for 5G as a result of the WRC-23 (and towards WRC-27) would contribute to the expansion of wireless mobile communications, supporting the request of the 5G mobile industry. Reasoning for supplementary IMT spectrum for dense urban applications should be clarified, especially with 6G mobile systems being still in an early stage in its research.

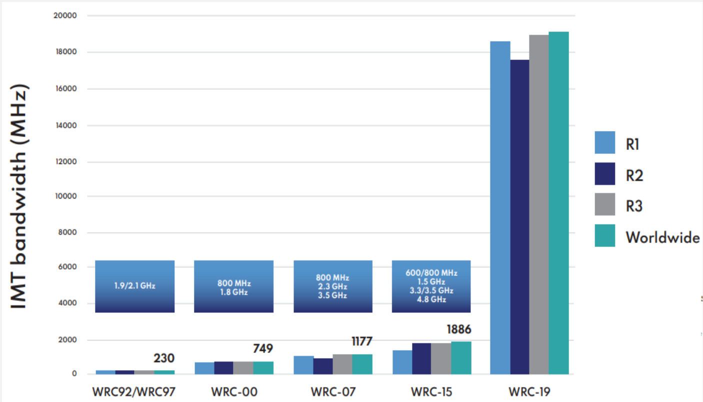

Figure 14: Amount of spectrum available for IMT (Credit: Sameer Sharma, GSOA)

The future development of IMT for 2030 and beyond is under study by the ITU-R regional organisations.[107] In this context, studies have been already initiated in the U.S for future auctioning of the X band, currently in use by remote sensing industries.[108] In any case, while the WRC identifies specific frequency bands for IMT deployment through the RR, this identification does not limit the use of those bands for other allocated applications, nor does it prioritise 5G or other mobile telecom services over other uses.[109] Each ITU Member state determines which bands will be made available for IMT in its country based on national or regional requirements.[110]

[106] GSOA, "WRC-23 Agenda Item 10: Studies on IMT identification in 7-24 GHz for 6G" (Link).
[107] ITU News. 2022. "WRS-22: Mobile broadband trends from 3G to 6G". ITU (Link).
[108] AIA, CSSMA, CSF, SIA. 2023. "Joint Association X Band Letter". AIA Aerosapce (Link).
[109] P. Ryan. 2005. "The Future of the ITU and its Standard-setting Functions in Spectrum Management". p. 349 In: The Standards Edge: Future Generation. Arkansas: Bolin Communications.
[110] ITU News. 2022. "An inside look at mobile broadband standards development". ITU (Link).

To conclude, enhancing the utilisation of spectrum resources encompasses a broad range of tools, models, and technologies. Such a goal will require innovative approach as well as identification of methods to assess spectrum availability and the potential of harmful interference. Notwithstanding those efforts, **some users have argued for spectrum to be set-aside for several applications**, including railroads and IoT, both at the domestic and international level. For instance, the WRC-23 Agenda Item 1.18 aims to allocate spectrum for commercial IoT purposes. Such an approach raises concerns that it limits the use of a radio allocation to a particular application, impeding its use to a variety of users even though they meet the technical parameter indicated in the RR.[111] Vice versa, this approach could also foster the growth of new uses of spectrum in bands where spectrum may currently be underutilised, thereby addressing the overall desire to efficiently use spectrum. The discussion for AI 1.18 has evolved and is being continued under AI 2.13 for WRC27.[112]

5.4 Improving Spectrum monitoring

Spectrum monitoring, prediction of interference risks, and planning solutions for potential interference scenarios are a crucial component of an effective spectrum management system, as it ensures that the use of authorised spectrum aligns with its intended usage.[113] It helps to identify and address equipment complexity, interactions, malfunctions, or misuse. Accurate, continuous and real-time monitoring of spectrum usage globally supports interference resolution functions, including those caused by unauthorised or non-compliant transmitters with exceeding out-of-band or spurious emissions.[114] This ensures quality reception of broadcasts, provides data for spectrum management processes, guides frequency selection, and prepares for Radiocommunication Conferences by providing spectrum occupancy reports and aiding in the BR programme organisation.[115]

During the Plenipotentiary Conference 2022, Resolution 186 was revised to:

> "*Strengthen ITU's role in transparency and confidence-building measures in outer space activities by instructing the ITU BR Director to make satellite monitoring facility information available to governments*."[116]

The document encourages Member States and space stakeholders to promote information sharing, capacity building, and best practices to bridge the digital divide and enhance the reliability of radiocommunication satellite networks/systems.[117]

Continuous monitoring and international coordination are vital to mitigate the increased risk of interference in satellite connectivity due to its rapid growth and expansion. Spectrum monitoring serves as a valuable source of information and verification in the spectrum management process.[118] It reinforces the role of cooperation agreements between ITU and national administrations in solving incidents.[119]

[111] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 156.
[112] ITU, "ITU-R Preliminary Studies for WRC-27" (Link)
[113] ITU News. 2022. "Space monitoring at the core of ITU Radiocommunication activities". ITU (Link).
[114] Limitations include some services such as GNSS, or passive and radio astronomy services that operate at power levels that can only be monitored with a very dense network of interference detection sensors. With very narrow beams at higher frequencies this could also be a challenge.
[115] The BR organises monitoring programs globally, regionally, or limited to specific areas or administrations.
[116] ITU, 2022. "Highlights: ITU Plenipotentiary Conference 2022". ITU (Link).
[117] ITU. 2022. "Resolution 186 (Rev. Bucharest, 2022)". ITU Publications (Link).
[118] ITU. 2011. "Handbook Spectrum Monitoring". ITU (Link): 4-5.
[119] ITU News. 2022. "Space monitoring at the core of ITU Radiocommunication activities". ITU (Link).

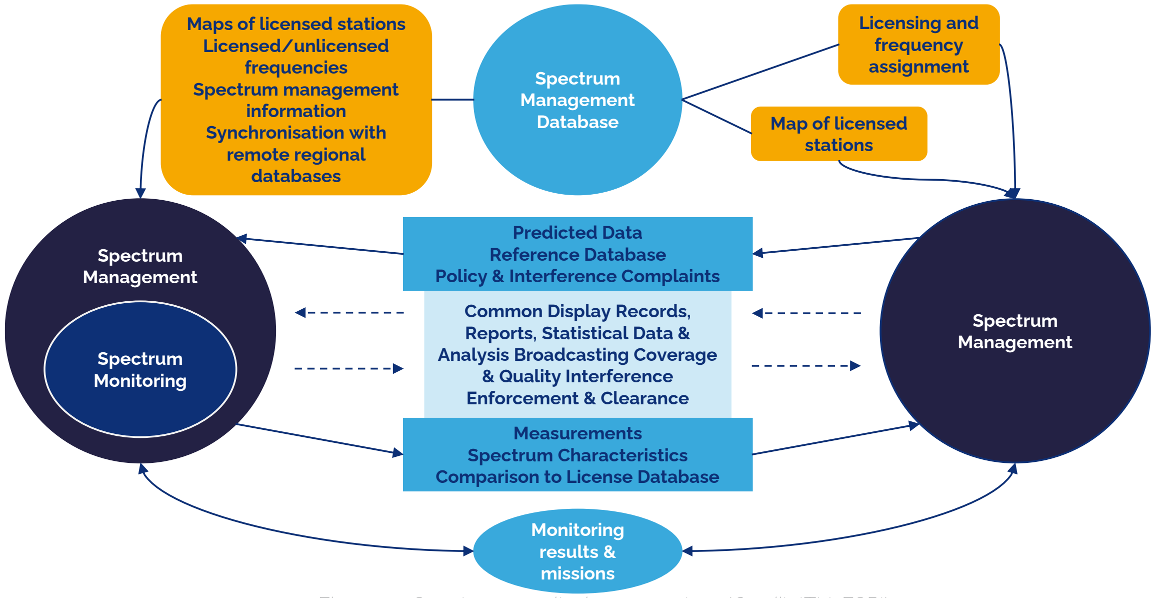

Figure 15: Spectrum monitoring ecosystem (Credit: ITU, ESPI)

Recommendation 36 (WRC-97) urged **ITU-R to study and recommend the necessary tools to achieve global monitoring coverage for efficient resource utilisation**. Administrations were encouraged to provide monitoring facilities pursuant to Article 16 RR (such as establishing central offices and/or HF monitoring stations), cooperate in requested monitoring programs, and address the monitoring of emissions from space stations.[120] Specifically, administrations with space monitoring facilities were encouraged to participate in the international monitoring system and notify the Bureau "of their monitoring stations for inclusion in List VIII (Section III)".

Regulatory provisions, including those outlined in RR No. 16, govern "*the establishment and operation of the **international monitoring system***."[121] The latter **is comprised of designated monitoring stations** operated by administrations, public or private agencies, joint monitoring services, or international organisations. The system coordinates monitoring activities to meet international requirements for collecting, exchanging, and publishing information. Administering authorities determine if the technical standards followed by these stations align with ITU-R Recommendations and communicate this information to ITU.[122] ITU publishes data on these stations and the centralising office's name in the List of International Monitoring Stations (List VIII).[123] As a matter of fact, both Recommendation 36 (WRC-97) and RR No. 16, did not find broad application for space-based telecommunications.

The Bureau plays a vital role by organising regular and special monitoring programs, analysing the results, and facilitating their communication with administrations. For instance, RR No. 15 allows administrations to seek the Bureau's assistance in resolving harmful interference cases. However, for space services the BR exercises control mainly on the information provided by governments when issuing licenses to a mobile station or mobile earth station in compliance with RR No. 18.6, as well as in the framework of the administrative due diligence of Resolution 49 (Rev.WRC-07) and the BiU conditions of Resolution 40 (Rev.WRC-19). The BR relies on information (e.g., identifying sources, determining jurisdictions, and measuring field strength when needed) that can be obtained through international monitoring, which may involve organising special

[120] See RR No. 16 and RR No. 21 and 22.
[121] ITU. 2011. "Handbook Spectrum Monitoring". ITU (Link): 15.
[122] Stations with lower technical standards may be authorized to meet specific monitoring data needs.
[123] As mandated by RR No. 20 (§ 8). WP1C, Annex 1 to 1C/95-E - draft revision of Report ITU-R SM.[SMALL-SAT], 2020.

programmes with limited monitoring stations. Cases of harmful interference are reported in the Satellite Interference Reporting and Resolution System (SIRRS), from which the BR may require two types of information: first, the identification and location of potential sources of interference; second, the BR assesses the interfering station's field strength measurement.

Announced and operating large satellite constellations introduce additional complexities. Traditional fixed measurement sites are no longer sufficient to thoroughly test and verify satellites transmission and location on non-GSO. Some significant concerns arise from the increasing congestion of the non-GSO and its associated frequency spectrum, including the rise in the likelihood of signal harmful interference, the reliability (inc. legal certainty, transparency and interoperability) in licensing, and the potential lack of efficient use of spectrum and related orbit positions. An example of these new complexity factors can be found in the technical issue related to the limits on the power that large constellations can emit when communicating with ground terminals (Equivalent Power Flux-Density, EPFD), so as to protect GEO fixed-satellite and GSO broadcasting-satellite services from interference. In particular, this matter will be addressed under AI 7, topic J, with the aim of establishing a procedure for collaboration among administrations in ensuring the aggregated EPFD limits are not exceeded. This is in parallel to the discussion on a proposed AI for the WRC-27 for the modification of Article 22 RR regarding the review of EPFD limits, with concerns raised by GSO operators in this regard.[124]

National administrations must address these concerns by implementing radio monitoring capabilities that are able to provide a deep understanding of radio spectrum usage patterns over time. Innovative approaches are necessary to mitigate potential issues, such as collecting and correlating data beyond radio frequency elements, utilising scalable and transportable sensors that can be dynamically reconfigured, and leveraging on-board signal processing capabilities.[125] New solutions and measurement techniques are needed in vast or inaccessible territories. In this context, ground-based systems have shown some limitations, in particularly due to the limited monitoring range, the insufficient number of monitoring sites, the difficulties posed by complex ground morphologies and the labour-intense procedures in adverse weather conditions.

To this extent deploying radio-monitoring LEO spacecraft could represent an effective solution. Collecting comprehensive radio frequency data enables a mapping of the radio spectrum usage and an analysis of trends. Furthermore, the system can identify unused or congested spectrum, aiding spectrum allocation, frequency coordination, and future planning. [126]

Enhancement of the spectrum monitoring tools require the centralisation of the collected data, particularly for non-GSO constellations that only partially cover populated areas. Establishing a new level of cooperation between administrations is necessary to consolidate data collection and analysis. This collaboration will facilitate the correlation of similar events across the globe and enable the prediction of future occurrences. Nevertheless, **collecting and analysing data may become overwhelming for administrations**, potentially resulting in longer licensing processes or even deregulation in some cases. In this sense, developing tailored Artificial Intelligence capabilities could become essential to managing this challenge. [127]

Detecting and identifying unauthorised transmitters is functional to solving interference concerns. However, distinguishing between legal and unauthorised signals can be challenging, particularly in

[124] A. Marklund. 2023. "The Road to Dubai: SES Perspectives on WRC-23". SES (Link).
[125] G. Baraglia. 2020. "Emerging challenges for satellite spectrum monitoring". ITU News (Link).
[126] WP 1C, Annex 1 to Document 1C/95-E - draft revision of Report ITU-R SM.[SMALL-SAT], 2020.
[127] G. Baraglia. 2020. "Emerging challenges for satellite spectrum monitoring". ITU News (Link).

crowded frequency bands where authorised and unauthorised transmitters have similar modulation characteristics. Conversely, the **absence of a signal does not always mean an unused frequency or no assignment**; the assigned transmitter might not have been active during the monitoring period.[128] Therefore, **monitoring information and spectrum management records do not always have a straightforward relation**. Channel occupancy data only indicate frequency usage, not giving information on the specific signal transmitter. Similarly, the **presence of an assignment at a specific frequency does not guarantee that the measured signal comes from the assigned transmitter**. Additional methods like aural monitoring or direction finders may aid in identifying and locating illegal transmitters once their operation has been detected.

The challenges of spectrum monitoring for space non-GSO is not at the WRC-23 agenda nor addresses by the CPMs report. A detailed analysis of the allocated preparatory work for each ITU-R study group shows that WP 1C, which studies spectrum monitoring techniques, is not listed as a responsible nor a contribution group to any AI. On the other hand, Resolution 22-5 from ITU-R determines that SG1 should address the specific needs of spectrum management organisations in developing countries and focus on improving spectrum management practices. The considerations outline the relevance of spectrum monitoring to discussions about the use of computer-aided systems and participation from spectrum management personnel worldwide, including the ITU BR. It encourages administrations from developing countries to "*strengthen their national radio-frequency management organisation*."[129]

Ultimately, **a robust spectrum management system depends on an effective spectrum monitoring, as well as the reliance on inspection capabilities.** When interference complaints arise, monitoring helps identify the interfering signal's location, transmission type, and technical parameters for further investigation. The spectrum management database aids in determining if the source of interference is an authorised transmitter operating beyond its parameters, or an illegal operator. However, while rules and procedures should be oriented towards effective enforcement, aspects related to mandate, power, and resources for the establishment of such a mechanism should be further considered. Implementing an effective monitoring system is a massive endeavour, and while it represents an ideal ultima goal, due to regulators' limited resources, regulators continue to rely on operators to identify and notify them of instances of interference.

5.5 Balancing efficiency with equitable access to spectrum

ITU´s space-related regulations have traditionally been based on the First Come, First Served (FCFS) (and coordination before use) procedure with rights and obligation, in line with the **principle of efficient, rational, and cost-effective (economical) spectrum/orbit management and utilisation for equitable access**. Following the recognition of GSO and, later, other earth orbits as a limited natural resources in Article 33(2) of the 1973 ITU Convention, concerns of several developing countries for the progressive exploitation and congestion of GSO frequencies/orbital slots led Member States to implement a parallel equitable access procedure with frequency/orbital position plans for each country.[130]

In 1985 and 1988, the World Administrative Radio Conference (WARC) on the use of GSO and the planning of the space services utilising it convened in Geneva with the task "*to reconcile the principle*

[128] ITU. 2011. "Handbook Spectrum Monitoring". ITU (Link): 11-12.
[129] ITU. 2019. "Resolution ITU-R 22-5. Improvement of national radio spectrum management practices & techniques". (Link).
[130] ESPI. 2022. "Report 82 - Space Environment Capacity". ESPI (Link).

of guaranteed and equitable access with that of the efficient and economic use of two limited natural resources: GSO and the radio frequency spectrum."[131]

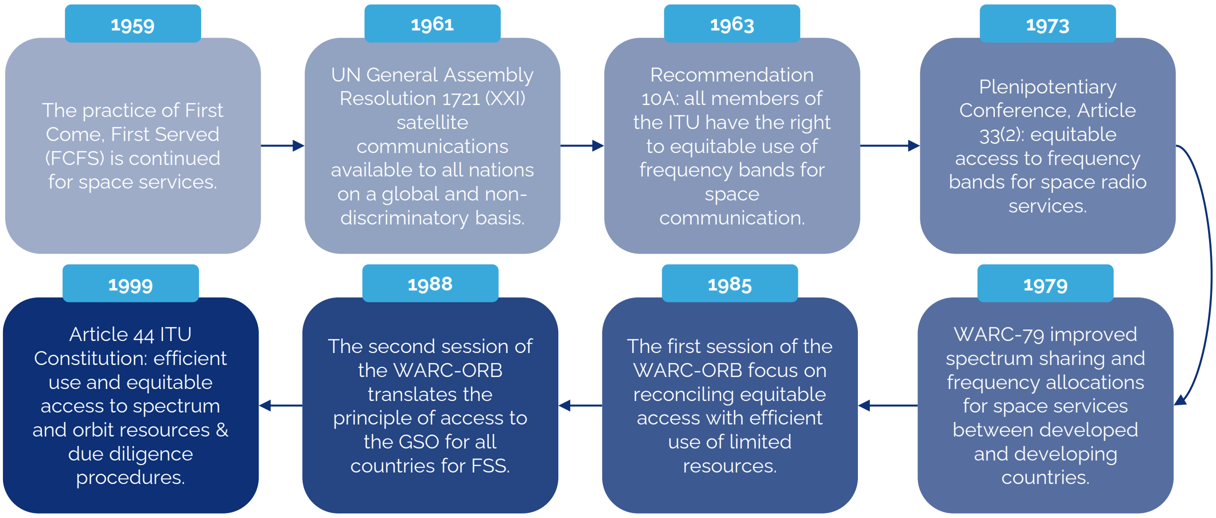

Figure 16: ITU space-related regulation (Credit: ITU, ESPI)

To guarantee equitable access, Article 44 of the ITU CC, **"Use of the radio frequency spectrum and of the geostationary satellite and other satellite orbits"**, paragraph 2 states that:

> *"in using frequency bands for radio services, Member States shall bear in mind that* **radio frequencies and any associated orbits, including the GSO, are limited natural resources and that they must be used rationally, efficiently and economically***, in conformity with the provisions of the RR, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries."*[132]

As a constant evolution of the Space Plans to remain efficient to provide equivalent access to GSO, at the WRC-19 the Resolution 170 was adopted, "*which provides the procedure to ensure equitable access to frequency bands under Appendix 30B (with the FSS Plan revised at WRC-07) by developing countries*." Additionally, Recommendation 16 (Rev. WRC-19) to the ITU-R continue to recognised the relevance and importance of equitable spectrum access: the **WRC-23 will continue to address challenges related to equitable access in GSO** in its AI 7 Topics D, E, F, H and I, titled "Space Plans for equitable access to GSO in the fixed or broadcasting satellite services" and AI 7 Topic K, titled "review of the special procedure in the Resolution 553 for enhancement of equitable access to broadcasting-satellite networks in the frequency band 21.14–22 GHz in ITU Regions 1 and 3 (Rev. WRC-15)."

While the **notion of equitable access is in priority (with secondary priority the efficient use of those planned bands) attached to the planning process of GSO systems**, in part of BSS and FSS bands, it has also been regarded as a widely accepted guiding principle for the regulation of space activity. As a common and finite resource, spectrum should indeed serve all applications, both space-based/terrestrial and fixed /mobile, radio astronomy and others. Regulations should ensure accessibility for stakeholders from all Member States and companies. In this context, additional **challenges and discussions arose from the introduction of large non-GSO satellite systems for commercial communications**.

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131 ITU. n.d. "1st session, Geneva, 1985". History Portal of the ITU (Link).
132 ESPI. 2019. Studies in Space Policy: Legal Aspects around Satellite Constellations v.19. Cham: Springer Nature. pp. 84-85.

Indeed, as LEO large constellations became more appealing, developing countries and commercial operators seek to guarantee frequency assignments availability. **Criticisms of the FCFS model in international forums** question the long-term and sustainable access to orbital space environment and spectrum, and the need to implement requirements around the principles of equity. The RR includes provisions mitigating the FCFS to create rights and obligation to coordinate with newcomers and justify technically reasons when compatibility is not possible. The coordination process on technical data is creating room (at least in theory, for more responsible actors) for accommodating coordination between stakeholders – first or later comer. While non-GSO offer a larger volume of available slots at multiple altitudes (called orbital shells by the Astro dynamic), **certain orbits are more favourable than others for cost-effectiveness and longevity of the system, also influencing the viability and utility of satellite constellations**.

Consequently, late comers may face less favourable conditions, such as the need to operate in harsher orbits, including those overlapping with the Van Allen belts or where the orbital debris density reaches its maxima.[133] However the difficulty of deployment of large constellation project within regulatory time limits is also an opportunity to reopen spectrum/orbit resources.

Achieving a balance between an efficient and equitable sharing of spectrum and orbits in a changing space environment is challenging, often resulting in some telecommunication systems lacking sufficient spectrum access. In contrast, enforcing equitable access in non-GSO through the implementation of additional measures, while aimed at also increasing efficiency, could have unintended consequences, further complicating regulatory compliance, especially for those operators and administrations lacking expertise.[134]

The matter has been raised at the 2022 ITU Plenipotentiary Meeting (PP-22) and is expected to be discussed at the WRC-23. **Resolution 218 on the "ITU's role in the implementation of the "Space2030" Agenda:** *space as a driver of sustainable development, and its follow-up and review process*" recognises the significance of Article of the 44, ITU Constitution. It highlights that:

> "*developing countries, least developed countries, small island developing states and landlocked developing countries face a lack of resources and expertise to address the complexities of the coordination processes*." The document argues that ITU should "*support the implementation of the Space2030 Agenda, especially the parts related to space services of overarching objective 3 of UNGA Resolution 76/3: improve access to space for all and ensure that all countries can benefit socio-economically from space science and technology applications and space-based data, information and products, thereby supporting the achievement of the SDGs.*"[135]

It instructs the Secretary-General and the Directors of the BR:

> "*To engage in the dialogue with relevant UN entities and promote BR's activities related to space,*" as well as "*to strengthen global partnerships and cooperation among Member States, UN entities, international and regional intergovernmental and non-governmental organisations, industry and private-sector entities in order to ensure that, through joint efforts and by taking advantage of the practical experiences and contributions of different stakeholders, the benefits of space will be brought to everyone, everywhere*."

The Resolution concludes with a need to:

[133] G. Long. 2020. "The Impact of Large Constellations of Satellites". JASON (Link): 22-23.
[134] P. Zhao. 2019. "The Benefits of Technology Neutral Spectrum Licenses". GMSA (Link): 8.
[135] The Space 2030 Agenda was adopted by the UN GA in 2021, on space as a driver of sustainable development.

"*Give high priority to the matter of equitable access to satellite orbits, taking into account the special needs of developing countries and the geographical situation of particular countries*."

The **dynamic stemming from the FCFS approach toward more equitable planning** would require a balance between "efficient and economic" use with its "equitable" access, and consequently need to be embedded in new ways of addressing and managing the Earth orbital environment at large, beyond just spectrum allocation.

5.6 Driving space sustainability concerns

The growing use of Earth's orbits by states, international satellite organisations, and private entities can only increase space congestion, and, consequently, the proliferation of space debris. The surge in satellite constellations enhances the risk of collisions and interference between satellite systems, contributing to concerns regarding the long-term sustainability of space activities. Large non-GSO constellations are posing unique challenges for national regulatory processes, and for the international outer space regime at large, **increasingly leading to the potential overuse of LEO**, both from a physical and radio frequency perspective. While national regulatory regimes have been historically associated with oversight purposes, they are also increasingly designed to ensure the sustainability of the space environment. This is relevant when considering that both spectrum and orbits are considered limited natural resources, as affirmed by policy and regulatory documents, including article 44 of the ITU CC.

In 2022, the ITU Plenipotentiary Conference (PP-22) released the **Resolution 219 on the "sustainability of the radio-frequency spectrum and associated satellite orbit resources used by space services."**[136] The resolution underscored the urgent need to review technologies used in satellite networks in GSO, as well as the increased numbers of satellites within non-GSO systems, with a view to addressing them, if necessary, in the RR and in the processing of frequency assignments by the BR. The document noted that such a challenge related to the deployment of non-GSO satellite systems should be addressed before those systems are launched.

The Resolution emphasises the significance of a sustainable approach to radio spectrum utilisation in space.[137] It is the result of deliberations on the challenges posed by interference and other adverse consequences that arise from the increased use of shared spectrum and orbital resources in non-GSO systems.

As a result of the Resolution, Member States have been invited to "*instruct the Radiocommunication Assembly (RA) to urgently **perform the necessary studies through ITU-R study groups to address the increasing use of radio-frequency spectrum and associated orbit resources in non-GSO orbits and the long-term sustainability of these resources, as well as on equitable access to, and rational and compatible use of, the GSO and non-GSO orbit and spectrum resources**, consistent with the objectives of Article 44 of the Constitution*."

This Resolution represents the first step in tackling harmful signal interference and other harms associated with the increased use of shared spectrum and orbital resources. However, some Member States are unable to settle on what is meant by "harms" and "issues". More neutral language was proposed to ensure the long-term sustainability of the Earth orbit environment and equitable access to the non-GSO orbit. In addition, **some Member States raised concerns on the fact that**

[136] ITU. 2022. "Highlights: ITU Plenipotentiary Conference 2022". eTrade for all (Link). See also ITU. 2022. "Final Acts of the Plenipotentiary Conference Bucharest, 2022". ITU Publications (Link).
[137] Access partnership. 2023. "Driving Space Sustainability". Access Partnership (Link).

such a matter would not fall within the scope of the ITU's mandate, especially when related to sustainability aspects such as space traffic coordinator, and debris mitigation and remediation. The result of the study on implementation of the Resolution will then be submitted by the Director of BR to the WRC-23 and, likely the next WRC in 2027, for its consideration, implementation, and discussion around matters which remain unresolved.

The commitment of ITU on space sustainability is strengthen by **Resolution 218 on the "ITU's role in the implementation of the "Space2030" Agenda."** Previously, ITU has provided guidance about disposal orbits ("graveyards") for satellites through the Recommendation on the Environmental protection of the GSO.[138] While deorbiting capabilities will remain the preferable option, a similar guidance for non-GSO should be considered.[139]

Scientific services are also facing more challenges from the increased activity in non-GSO orbits. Radio Astronomy stations are normally sited in very remote areas of the planet to minimise the human-made radio activity, some even protected by national legislation as Radio Quiet Zones, are seeing a rapid increase in satellite density in the skies.[140] Large constellations of non-GSO satellites are visible from any point on Earth bringing new challenges for the very sensitive radio receivers in radio telescopes.[141] However, satellite operators have been working closely with the astronomy community to address these issues. For instance, SpaceX has been commended by the Radio Astronomy stations on their engagement in seeking solutions together.[142]

Another effect of the increased use of space is the reflection of sunlight from objects in LEO, gradually changing our view of the night sky and affecting optical telescopes, especially those designed to detect asteroids with a possible collision course with Earth. While this effect is not regulated under ITU, it is an integral part of the topic of space sustainability.

Concerns regarding orbital space and spectrum congestion are expected to escalate as the number of satellites and space objects launched rises exponentially at an unprecedent rate, thus requiring an urgent need to strengthen and increase an internationally coordinated action and decision. Recognising the evolving nature of space technologies and the associated concerns regarding space sustainability, **ITU should remain committed to supporting endeavours towards a more sustainable space environment**.

To support actions of governments in addressing these concerns, key international meetings (like the WRC-23) gathering actors from the private sector and administrations in a decision process by consensus are essential to accelerate a globally coordinated solution.[143] Collaboration such as the recently announced ESA-ITU cooperative effort for the characterisation and geolocation of satellite interference, would also be crucial.[144]

[138] ITU. 2010. "Recommendation ITU-R S.1003.2 (12/2010)". ITU (Link). It is not legally binding.
[139] Graveyard orbits could be considered for NGSO satellites operating above LEO.
See G. Di Mauro et al. 2021. "ITT 7210 – End-of-Life Disposal Concepts for Lagrange-Points and HEO Missions". ESA (Link).
[140] ITU. 2021. "Report ITU-R RA.2259-1". ITU (Link).
[141] C. Walker (ed.). 2022. "Dark and Quiet Skies II for Science and Society". UNOOSA/Noirlab (Link).
[142] J. Foust. 2023. 'NSF and SpaceX reach agreement to reduce Starlink effects on astronomy'. SpaceNews (Link).
[143] J. Manner. 2023. "The Regulatory Roadmap for 2023". Via Satellite (Link).
[144] J. Foust. 2023. "ITU emphasises importance of space sustainability". SpaceNews (Link).

A new approach to Outer Space Governance

The sustainability challenge that the space environment is currently addressing has called for **new approaches, philosophies, and concepts** that could effectively mitigate and remediate the risks related to increasing physical and spectrum congestion. The challenge faced can only be addressed through strong international cooperation and a transformation of present and future outer space governance frameworks, maximising the opportunities of outer space and minimising the short and long-term risks.

While maintaining the centrality of Member States and their leadership on intergovernmental processes, an agile, as well as broad and multi-stakeholder outer space governance response should be pursued. This framework should build on the work that has historically been done on space sustainability by different administrations and supranational bodies, including UN COPUOS, multilateral bodies of the GA, ITU, and other entities such as the IADC, whilst also acknowledging a degree of overlap between their work.

This narrative is confirmed by the **UN Secretary General Policy Brief NO7** commenting on the **overlap between intergovernmental entities' missions relating to space security, safety, and sustainability**.[145] A new governance framework for various areas of space sustainability should be explored in a cooperative format between bodies of the UN system, considering the UN space treaties and any other means of international cooperation, whilst also including a platform to **broaden operational stakeholder inclusion**.

In particular, the latter should serve to increase contribution more effectively from external experts, to keep pace with technological advancements and the definition of operational requirements. When focusing on synergies between UNCOPUOS and ITU, the intertwined dynamics between effective spectrum management and the physical capacity of the space environment, as well as the level of exchange between space and spectrum entities, should be explored. For instance, ITU´s database has vast amounts of data on satellite networks filings (e.g., orbital parameters) that could be a useful complementary element when discussing Space Situational Awareness, Space Traffic Management or collision avoidance, especially if synergised with additional data sources - as previous attempts has already demonstrated.

Achieving a sustainable space environment necessitates **worldwide collaboration and resource-sharing at the intergovernmental level** under the auspices of the UN. UN COPUOS, the ITU-R, WRC, as well as bodies outside the UN-system that delas with space sustainability, should continue to operate under different mandates and in different institutional setups. However, an effective space sustainability international coordination scheme and collaboration between different regulators will ensure some best practices be taken forward to enhance and reinforce the effectiveness of the respective regimes, and, more generally, the broader outer space governance. This is especially needed when dealing with the above-described related challenges and to ensure the continued viability and sustainability of space activities.[146]

A clear opportunity to enhance outer space governance is provided by the UN Summit of the Future in 2024. [147]

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[145] UN. 2023. "Our Common Agenda Policy Brief 7: For All Humanity – The Future of Outer Space Governance". (Link): 10.
[146] COPUOS. 2023. "A/AC.105/2023/CRP.23". UNCOPUOS (Link).
[147] UN. n.d. "UN Summit of the Future in 2024". UN (Link).

6 European Regulatory Environment for Spectrum

States play a key role in the multi-level (encompassing international, regional, and national) spectrum management system. When drawing attention to the international level, with its associated challenges, towards national systems, **the sovereignty that states maintain over the use of spectrum in their territories** should be highlighted. Indeed, the allocation and assignment of frequencies various uses and user occurs at the state level, which retain flexibility and autonomy in managing the spectrum bands within their territory, with the same applicable for space services.

National spectrum management approaches

National spectrum management can be defined as the system consisting of "*structures, procedures, and regulations whereby an administration controls the use of the radio spectrum within its geographical boundaries*."[148] These activities have the overarching objectives of ensuring the **availability of spectrum** for both public and private entities that contribute to the social and economic objectives (e.g., reduction of the digital divide), while at the same time making the **most efficient use possible** of the limited resource. These high-level objectives are translated into activities conducted as part of the national spectrum management system, including **spectrum planning, frequency assignment and licensing, liaison and consultation with national organisations, spectrum management financing, spectrum monitoring**. The international TFA (ITU RR No 5) and the national TFA represent the foundation of such a system.

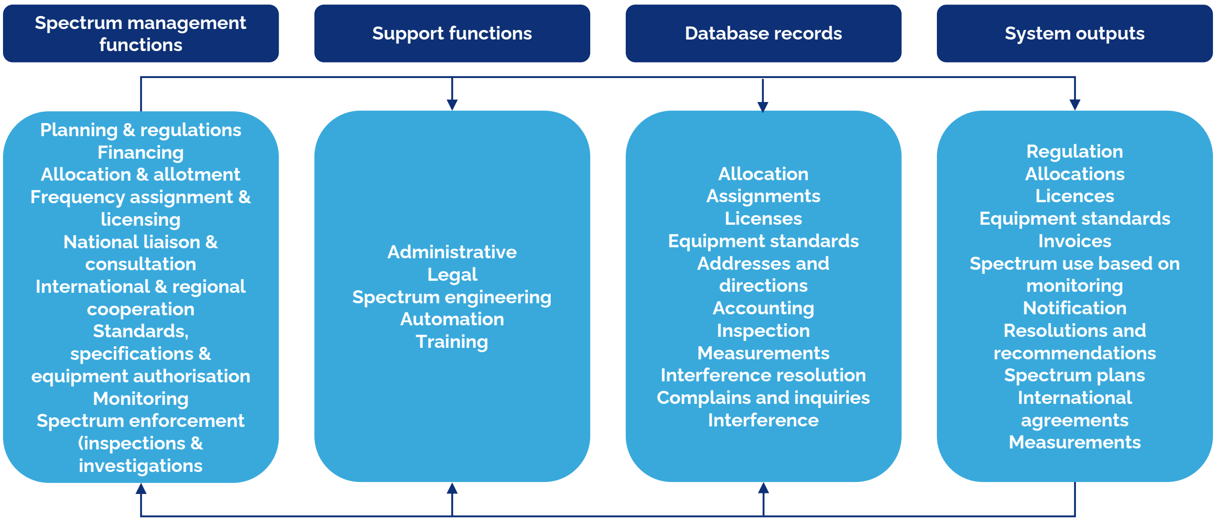

Figure 17: National Spectrum Management Systems (NSMS) (Credit: ESPI, ITU)

Different approaches to spectrum management can be pursued domestically.

Firstly, when focusing on the relation between the spectrum and space regulators, several approaches can be highlighted. Indeed, every European country has a different spectrum authorisation process (and different specific requirements that need to be met for the ITU filing procedures), a different satellite authorisation process (or sometimes lacking it entirely), and a different registration process to the UN Register of Objects Launched into Outer Space (usually dealt with by the Ministry of Foreign Affairs). For instance, in the French system the National Frequency Agency (ANFR) manages satellite filings and fulfils all ITU procedures, while the Ministry in charge of space, notably the Ministry of Economy, provides launch authorisations. In the UK, the Office of Communications (Ofcom) is responsible for spectrum management and filings to the ITU,

[148] ITU. 2020. "Spectrum Management". Digital Regulation Platform (Link): 4.

while the Civil Aviation Authority (CAA) grants launch authorisations to satellite operators. The diversification in approaches results in a barrier for smaller operators, struggling to interface with the relevant point of contact for the different procedures. Germany is one of the few cases with a centralised approach where the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways (BNetzA), which is responsible for the assignment and transfer of frequency (and orbit) usage rights from the German government to the operators, consequently being the single interface for satellite operators. Recognising the value of a centralised mechanism, the practice of operators is sometimes oriented towards simply circumventing their national regulators and ending up filing with BNetzA.

Moreover, while some countries have a single regulator for private and public spectrum, other countries split such a responsibility between two or more agencies. In the U.S case, spectrum is allocated either by the National Telecommunications and Information Administration (NTIA) for federal use, or by the Federal Communications Commission (FCC) for commercial and non-federal use. In France, ANFR manages satellite filings and fulfils all the ITU procedures. Similarly, in the United Kingdom, Ofcom is the unitary regulator responsible for government and private spectrum. When more than one national body is entrusted with spectrum management tasks, a coordination between all the entities involved is deemed necessary and the decision process (contemplating the participation of private organisations) is defined.

The regulatory framework is usually based on a radiocommunication law complemented by several regulations and procedures adopted by national spectrum authorities with the aim to regulate the licensing process, define the necessary technical and operational standards, design the equipment authorisation procedures, and channel plans.[149] For instance, in France, spectrum is subject to the French Post and Electronic Communications Code. In 2021, Ordinance No. 2021-650 transposed Directive (EU) 2018/1972, altering the French regime. In the United Kingdom, Section 22 of the Communications Act 2003 is complemented with the Wireless Telegraphy Act 2006). In Germany, procedures are established under the 2021 Telecommunications Modernisation Act.

A reform of the licencing procedure at the national level (including reducing regulatory burdens and fees) has been initiated in different countries.[150] This is being seen in the currently **attempted reform of the licensing procedures adopted by the FCC**. Indeed, in March 2023 the Committee on Energy and Commerce of the House of Representatives, which is also entrusted with telecommunications matters, approved a number of space-related bills. [151] This includes the Satellite and Telecommunications Streamlining Act and the Secure Space Act, whose drafts had already been released in February with the aim to accelerate and increase the security aspects of FCC's licensing procedures, while also introducing safety and sustainability requirements. This especially is a direct consequence of the rising number of non-GSO applications. [152] Nevertheless, in July the bill was rejected by the House of Representatives because of concerns regarding the authority that it would have given to the FCC to regulate space safety and space traffic management. [153] Similarly, in early-2022 the FCC and NTIA launched a Spectrum Coordination Initiative to improve coordination within the U.S government on spectrum management and related policy issues. [154] This was then followed by an update to the Memorandum of Understanding

[149] ITU. 2020. "Spectrum Management". Digital Regulation Platform (Link): 6.
[150] M. Young & A. Thadani. 2022. "Low Orbit, High Stakes". CSIS Aerospace Security Program (Link).
[151] Energy & Commerce Committee. n.d. "Subcommittees". Energy & Commerce Chair Rodgers (Link).
[152] J. Rainbow. 2022. "Bipartisan legislation seeks to reform FCC satellite licensing rules". SpaceNews (Link).
J. Rainbow. 2023. "House subcommittee advances five satellite-related bill". SpaceNews (Link).
[153] J. Foust. 2023. "House rejects satellite spectrum licensing bill because of space safety provisions". SpaceNews (Link)
[154] FCC. 2022. "FCC, NTIA Establish Spectrum Coordination Initiative". Federal Communications Commission (Link).

between the parties.[155] In addition, in September 2023, FCC adopted new rules to expedite and facilitate its processing of space and earth station applications.[156]

European Regulatory Framework for Spectrum Management

When focusing on the European framework for spectrum management, several entities contribute to shaping policy and regulatory means on top of the national prerogatives. The common European policy position to ITU is formulated by a cooperative body, called the **European Conference of Postal and Telecommunications Administrations (CEPT).**

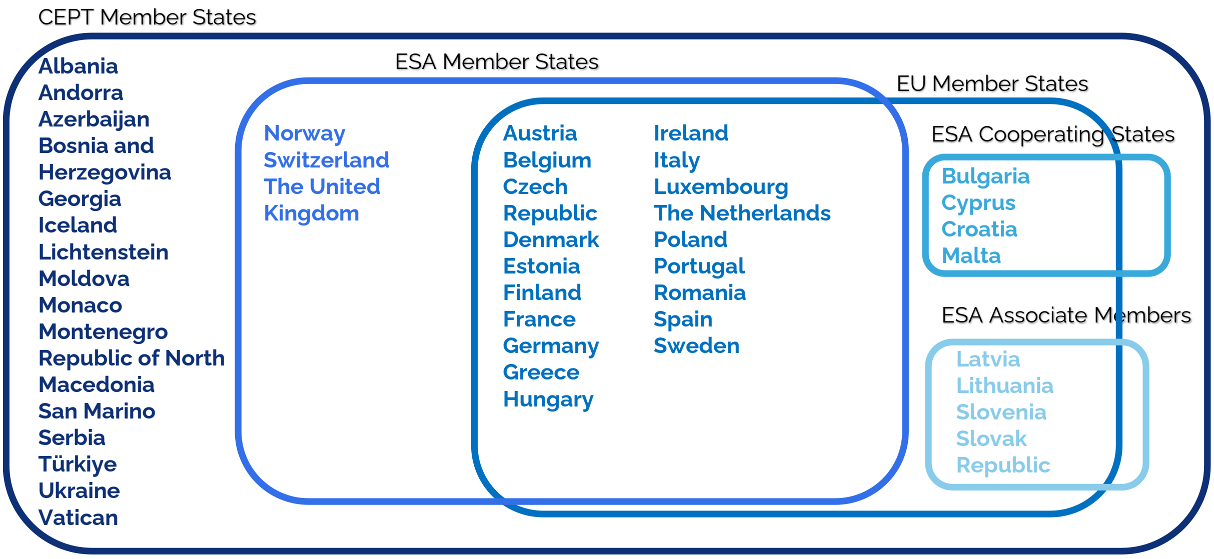

Figure 18: Country membership in relevant European frameworks (Credit: ESPI)

Its **Electronic Communications Committee (ECC)** produces non-binding Decisions, Recommendations and Reports through a consensus decision-making process among its 46 members. The work of the ECC is supported by the **Conference Preparatory Group (CPG),** in charge of preparing the European Common Proposals for the WRC, as well as conducting studies on relevant matters.[157] The CEPT also supported the creation of the **European Telecommunications Standards Institute (ETSI)** and maintains strong links through a Memorandum of Understanding to produce harmonised standards. More specifically, ETSI reports on the technical, legal, and economic aspects of standardisation for new radio systems and ICTs. Finally, the **European Commission (COM)** plays an overarching role in the regulatory environment. By designing and managing the framework of regulation for aspects of spectrum management, COM is supported by several bodies providing advice, notably the **Radio Spectrum Policy Group (RSPG).** Overall interaction is maintained through CEPT reports released under the mandate of COM, whilst ETSI is recognised by COM as the European Standards Organisation (See Annex B). Generally, **COM works with Member States to develop EU-wide spectrum policies**, harmonise usage, and enhance the availability of spectrum information.

The fundamental 2002 Radio Spectrum Decision refers to the provision of satellite-based communication services with intrinsic geographical coverage beyond the borders of a single Member State as one of the key reasons for requiring a coordination of radio spectrum use at the European level, in addition to an adequate representation of the EU at ITU and its WRC.[158]

[155] FCC. 2022. "MOU Between the FCC and NTIA on Spectrum Coordination". FCC (Link).
[156] FCC. 2023. "Report & Order & Further Notice of Proposed Rulemaking (FCC 23-73)." FCC (Link).
[157] ECC. 2023. "Status of CEPT Preparation for WRC-23/RA-23". ECC CEPT (Link).
[158] EP and Council. 2022. "Decision No 676/2002/EC of the European Parliament and of the Council". (Link).

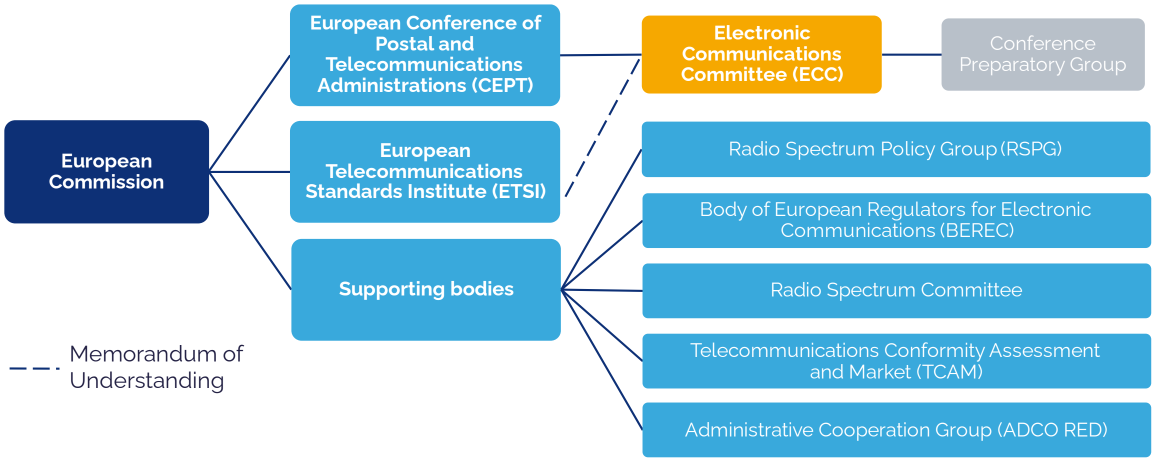

Figure 19: European Ecosystem for Spectrum Management

Harmonisation is achieved with a threefold system:

- The **RED Directive** establishes a regulatory framework for placing radio equipment on the market, with particular attention to the efficient use of the radio spectrum. Building on this, the Commission, supported by the Telecommunication Conformity Assessment and Market (TCAM), formulated an Implementing Decision (M/536) for the request to ETSI and CENELEC (another standardisation body recognised by the EU) to develop harmonised standards. The harmonisation mechanism is based on the fact that compliance with these standards creates a presumption of conformity with the requirements set by the RED Directive.
- The **EECC** has among its objectives ***the "development of common rules and predictable regulations for the effective, efficient and coordinated use of radio spectrum"***, thus entrusting member states with the responsibility to cooperate in the strategic planning and coordination of radio spectrum through the RSPG. Moreover, member states are requested to provide predictable regulation for radio spectrum licensing for at least 20 years to foster investments, particularly in the 5G connectivity.[159]
- The **2002 Radio Spectrum Decision** (676/2002/EC), with its Article 4(3), is used as the legal basis for the adoption of several implementation decision for the harmonisation of specific bands.[160] The technical reports released by the CEPT in response to the mandates issued by COM contribute to the preparation of such Implementing Decisions.[161]

While the positions for WRC on European level are taken by CEPT in the so-called CPG under the CEPT/ECC with the aim is to have an ECPs (European common proposals) on all the AI of the WRC-23; the role played by COM through its harmonisation activity also has an impact on the **preparation of the ITU WRC**. Indeed, despite the fact that the EU lacks voting rights in ITU, thus relying on its Member States to achieve its policy objectives, the EU participates the Conference as a sector member, without voting rights but with the possibility to participate in the study period.[162] To this extent, the EU position is established by a Decision of the Council following the COM Proposal, on a subset of the WRC AI. In particular, EU-positions are only taken on AI in cases where EU treaty aspects are affected, such as Single Market issues, ECS bands (Mobile bands and RLAN), and cases of coordination which fall under the EECC (Art. 4 and 28). All EU positions are said to be consistent with the ECP developed within CEPT.[163]

[159] COM. 2018. "European Electronic Communications Code". EUR-Lex (Link).
[160] In February 2022, COM adopted two implementing decisions for the use of radio spectrum by short-range devices within 874-876 and 915-921 MHz frequency bands, and on the harmonisation of the 900 MHz and 1800 MHz frequency bands, for their use for 5G applications (Implementing Decisions (EU) 2022/172 and 173 respectively). EU. 2022. "Commission implementing decision (EU) 2022/173". Official Journal of the European Union (Link).
[161] COM. "Harmonising spectrum for enhanced connectivity". COM (Link).
[162] ITU. n.d. "Sector Members". ITU (Link).
[163] COM. 2019. "EU at the WRC-19". European Parliament (Link).

In preparation for the WRC-23, COM submitted a proposal to the Council in May 2023, which was formally adopted in September 2023 as the EU joint-position to the WRC.[164] Whilst COM has declined to comment on the details ahead of the WRC, the position will be largely focused on global frequency allocation from 2030 onwards. There is speculation that the UHF band, which is currently allocated to broadcast use, will see mobile services added on a secondary level. This has resulted in strong interest from mobile network operators on their ability to acquire usage rights, especially as these 470-694 MHz frequencies will allow for widespread coverage.[165]The discussion is ongoing, with high probability that the outcome will be in line with the RSPG opinion from December 2022.[166]

As aforementioned, **Members States in Europe have different policy and regulatory frameworks.** This fragmentation is particularly problematic when compared to non-European policy approaches, like FCC. The latter could be regarded as indeed more "agile" and "flexible" while the first could be considered "rigid" and "conservative" under different perspectives. Despite drawing from the COM TFA, EU countries' TAFs and regulations have differences that impair operating across EU countries for what concerns Space (and in particular SOS, EESS, SRS services). S-band and X-band, the backbone of EESS satellites, are wholly available in some countries, available only for Military/Governmental operators in others, and available only for certain segments in others. These divergences must be addressed if spectrum sharing is the goal.

Moreover, **the need for innovative approaches and increasing spectrum sharing is currently driven by the advent of 5G and the consequent demand for spectrum**.[167] In this context, while the U.S (for instance with the CBRS) and some parts of Asia have made progress, Europe faces challenges in addressing access to spectrum due to structural issues involving a lack of enforcement powers compared to other institutions abroad, multiple countries with a plethora of local interests, and the presence of different regulatory regimes.[168] With this premise, RSPG published a Report on Spectrum Sharing in February 2021, followed by a subsequent Opinion published in June, with the aim of facilitating consensus on a European framework for sharing spectrum bands.[169] However, the RSPG Report lacked any "space" related practical sharing pilots. In 2023 a similar direction was identified at the national level, with the UK government releasing its policy paper on spectrum.[170] This made explicit reference to engaging with Ofcom UK (the national body responsible for spectrum management) on spectrum sharing arrangements, as well as linking spectrum's key role to the nation's space sector ambitions.

In addition to the incentive-based spectrum management applied in the case of the relocation of the C band in the U.S (See Thematic Box in Chapter 3), two mechanisms are worth mentioning. First, the (not so successful) creation of spectrum secondary markets since the 2000s, with the FCC introducing a system of spectrum rights transactions without requiring an assignment of the license to the new user.[171] Second, *use it or lose it* conditions for 5G licenses, following a principle already implemented in Europe for mobile spectrum auctions and by ITU for non-GSO FSS satellite networks.[172] Similar approaches are in place in European countries, such as Austria.[173]

[164] European Parliament. 2023. "Reply to Parliamentary Question E-001811/2023(ASW)". European Parliament (Link).
[165] J. Krieger. 2023. "EU opts to keep UHF band for broadcast at WRC-23, but adds mobile". Broadband TV News (Link).
[166] COM, RSPG. 2022. "Opinion on the ITU-R World Radiocommunication Conference 2023". RSPG (Link).
[167] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 123.
[168] J. Walko. 2021. "Europe Struggling to Share Spectrum". EE Times (Link).
[169] COM. n.d. "Promoting the shared use of Europe's radio spectrum". COM (Link).
[170] Dept. For Science, Innovation & Technology. 2023. "Spectrum statement". UK GOV (Link).
[171] J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. pp. 146-149.
[172] K. Bode. "Do we need use it or lose it spectrum rules?". DSL Reports (Link). See also J. Manner. 2022. Spectrum Wars: the Rise of 5G and Beyond. Boston: Artech House. p. 148.
[173] Further details on the case study of Austria can be found in RIS. 2021. "TKG 2021 Federal Act". GV.AT (Link).

Finally, a crucial economic driver for efficient spectrum regulation is fostering emerging technologies and services which spur competition and innovation in the satellite industry. In some cases, spectrum regulatory frameworks are not revisited with sufficient regularity, potentially creating an environment that encourages legacy operators to maintain effective monopolies over certain bands.

European Harmonisation of 2 GHz frequency for MSS

In February 2007, COM adopted Decision No 2007/98/EC1, which aimed to promote European harmonisation of the use of 2 GHz (1980-2025 MHz, 2170-2200 MHz), frequency bands by systems providing Mobile-Satellite Services (MSS). This was to **prevent a fragmented internal market, avoid harmful interference situations**, and utilise MSS spectrum efficiently. What followed was the legal framework established by Decision No 626/2008/EC in June 2008. This outlined the allocation procedure at the EU level for MSS operators.[174] It also defined common obligations of the selected operators to which the rights of use were subject, namely:

- Selected operators shall use the assigned MSS spectrum.
- Six to nine milestones (set out in the Decision) are met within 24 months of selection.
- Operators shall honour any commitments given in their application.
- Annual reports will be provided by the operators to the competent authorities of all MS.
- Any necessary rights of use and authorisations shall be granted for a duration of 18 years.

Following the beauty contest procedure, MSS spectrum was allocated to **two "Pan-European" operators to achieve an EU-harmonised frequency band of 2 GHz**. Inmarsat (acquired by Viasat in May 2023) and Solaris (now EchoStar) were granted licences until mid-2027, after being assessed on both their technical and commercial abilities, as well as the technical and commercial quality of the MSS offered.[175] The operators also had to obtain authorisation at the national level for the use of complementary ground components. The purpose of authorisation Decision No 2009/449/EC was to create an internal market open to competition, whilst reducing digital inequalities through improved coverage in less-developed areas of the EU.[176] **While the "pan-European" approach arguably prevented other MSS operators from entering the market for 15+ years**, concerns have emerged that the allocated MSS spectrum remained underutilised until recently and could have been used more efficiently.[177]

In November 2022, the RSPG, under the direction of COM, initiated its review and reconsideration of the EU regulatory framework on MSS. This was in part due to the upcoming expiry of licenses in 2027, but also due to the necessity to maximise the efficient use MSS spectrum.[178] Recent technological and market developments require a renewed assessment of the licensing allocation. Actors has been invited to assess different possible scenarios for the use of the 2 GHz MSS frequency band beyond 2027 and to provide recommendations as to the most appropriate way forward taking into consideration the efficient and effective use of the 2 GHz MSS frequency band for the period after 2027.

In line with upcoming EU digital and green policies (e.g., the Digital Decade Policy Programme 2030 and European Digital Single Market strategy), COM will produce a draft opinion for public consultation in October 2023, with a final opinion to be published in February 2024.

[174] ANACOM. 2016. "Issue of right of use of frequencies to Echostar". ANACOM (Link).
[175] Inmarsat. 2023. "Viasat completes acquisition of Inmardat." Inmarsat (Link).
[176] COM. 2020. "Selection and authorisation of mobile satellite services (MSS)". EUR-Lex (Link).
[177] Friedner et al. 2017. "Study on Spectrum Assignment in the European Union". COM (Link). p. 58.
[178] RSPG. 2022. "Request for an Opinion on the Future of the EU-level regulator framework". COM.(Link).

7 A European perspective on Spectrum Policy

There is a significant history of cooperation between European regulators regarding spectrum. This should be further leveraged and evolved to attain an even better level of harmonisation in the future, and a more efficient use of spectrum bands to ensure European competitiveness. In this context, four policy perspectives have been considered for the medium to long-term evolution of the European spectrum framework in the space domain:

Figure 20: ESPI Perspectives on European Spectrum Policy

As a result of the four policy dimensions outlined above, this study proposes four recommendations for further consideration in the development of space spectrum policy by European policymakers.

7.1 Developing a European approach to spectrum sharing

A reflection on how stakeholders can work together to develop a European approach to spectrum sharing for space radiocommunication services should be strengthen. This includes exploring how emerging technologies can be leveraged to maximise the efficiency of key spectrum bands and respond to the needs of European stakeholders. Questions to be addressed include how to balance spectrum sharing with exclusive licences and how to solve the potential conflict between spectrum sharing approaches and auctions of spectrum bands.[179] . A solution to balancing exclusive licensing with auctioning, is that of the private management rights regime. This allows for a re-selling of spectrum in underutilised areas and permits spectrum re-use, although actions should be considered to monitor its utilisation to prevent spectrum hoarding and monopolistic tendencies.

Notwithstanding the benefit to encourage spectrum sharing practices through regulatory framing, regulators considering employing such rules should also consider the operational implementation of spectrum sharing, and ensure the availability and feasibility of technical and resourcing capabilities to enforce these sharing rules. This would potentially serve to alleviate burdens on the licensees as a whole. Ultimately, the development of an adaptive **spectrum sharing roadmap could be considered.**

Recommendation One: To develop a spectrum sharing roadmap for Europe

7.2 Synergising knowledge and expertise within Europe

An environment that facilitates effective knowledge-transfer and foster expertise is vital. The creation of a centralised information point (or "one-stop shop") to help navigate access to spectrum, mission authorisation, space object registration, and earth stations licensing across EU member states could pave the way for further coordination.

[179] T. Ramachandran. 2022. "No auctioning satellite spectrum". Financial Express (Link).

EU states could pool resources to support ITU filings for other Member States that themselves lack adequate funds or expertise to do so. Additionally, expertise to support ITU filings could be synergised under an existing body in the European regulatory landscape, such as the ECC or CEPT. Moreover, **EU DG DEFIS, EU DG CONNECT, as well as ESA could play a role**, providing advisory and legal services to guide (small) operators and help them navigate their national frameworks. Furthermore, workshops for national regulators, space agencies, and industry could provide an opportunity to share best practices and bring them closer to the needs of the operators and user segments.

This would address the challenge for European regulators who are often not aware of the space sector. Arguably, they are neither familiar with ITU software and processes, nor with the UN Register of Space Objects and responsibilities coming from International Space Law. Thus, **an environment to expand and facilitate expertise would be beneficial** at both the regional and international level.

Recommendation Two: To create a European one-stop information point for spectrum & space

7.3 Strengthening ties between spectrum and space authorities

When focusing on the use of spectrum for satellite networks, **space stakeholders would benefit from a closer exchange and coordination between national spectrum managers and authority dealing with space operations** (e.g., for granting the launch operator licence or registering the space objects). Indeed, this institutional set up is tackled at the national level with several different models, from cooperative schemes of both spectrum and space organisations in the licensing procedures, to diversified cooperation mechanisms significantly influenced by the single administration's structure.[180]

One proposed solution could go beyond the coordination of space agencies and space regulators with their national telecommunications regulators, reaching a whole-of-government approach **– a single coordinated interface at the national level**- to licensing procedures and increasing their role in the meetings of ITU. A source of inspiration could be the Space Frequency Coordination Group (SFCG), a voluntary informal technical group of frequency managers gathering representatives from major space agencies and providing a forum for multilateral discussions on spectrum matters of mutual interest.[181] However, commercial users that wish to utilise these frequencies may still question the transparency of this process, which highlights the complexity of ensuring cohesion between private and public interests.

Recommendation Three: To establish a single national coordinated interface to licensing

7.4 Harmonising spectrum management systems in Europe

Consensus-building remains at the forefront of the European approach to spectrum management and standardisation. However, the multitude of actors within the regulatory landscape, with multiple bodies providing for different spectrum authorisation process and different specific requirements

[180] ESPI. 2023. "Summary Report: Regulator to Regulator Dialogue". ESPI (Link).
[181] SFCG. n.d. "Space Frequency Coordination Group (SFCG)". SFCG (Link).

that need to be met for ITU filing procedures is the result of a fragmented ecosystem, and represent a challenge for the space industry.

A **change of spectrum regulation is deemed necessary,** notably towards regional harmonisation of a fragmented landscape at a national level. This will be of high economic value as operators avoid the burden of multiple requirements procedures in all Member States and it avoids interference along country boundaries. A step towards such a pan-European system is represented by a light **harmonisation of licensing procedures** (e.g., common format for applications or the harmonisation of the requirements for a filing). Such an evolution would not be in contrast with member states retaining sovereignty and economic benefit from spectrum licensed on their territory. In addition, **the proposal for a coordinated pan-European licensing process** could improve fragmentation, providing a more harmonised system, reducing access barriers to space and spectrum for new entrants to the market, and enhancing competitiveness.[182]

Recommendation Four: To harmonise licensing procedures at the European Level

ESPI´s Role and actions in Space Spectrum Policy

With this Report, ESPI aims to initiate a process to:

- provide an overview of the spectrum management regime, including the **policy, regulatory and commercial implications for space**, and
- foster an active forum for the analysis and discussion on spectrum management policy, **facilitating the dialogue between the spectrum and space community**.

In line with the **ESPI Vision 2040**,[183] ESPI's research agenda includes under the umbrella of "space as an asset", a transversal research theme addressing infrastructure and capabilities required for access to space, launchers, spaceports, and ground infrastructure. It includes the orbits and spectrum required by space missions as a pre-requisite to fulfil their purpose.

Short term implementation items to the Report include the organization of an **Online Launch Event** to further discuss the outcome of WRC-23 and beyond, as well as additional **open and close-door events.**

In addition, leveraging this Report as a foundation for further research activities, ESPI will continue to support stakeholders with strategic analysis linked with a variety of key topics related to spectrum policy, including consideration for the enhancement of the space & spectrum governance, cislunar spectrum management framework, regional harmonisation licensing procedures, and market access & competitiveness policy assessments. A vision for a Space Law/Space mission authorisation mechanism and an analysis regarding the EU´s mandate for such a development should be further considered.

ESPI welcomes proposals and contributions from policymakers and industrial stakeholders, as well as the broader space and spectrum community. External stakeholders are kindly invited to contact the Lead author of this Report.

[182] European Parliament. 2007. "Study on A Common European Spectrum Policy". EU (Link): 24. See also COM. 2016. "Study on Spectrum Assignment in the European Union". COM (Link): 61, 62. Coordinated license exemptions for certain classes of VSATs have been present in Finland, Sweden, and Denmark since 2001, showing unified regulatory standards implemented through national spectrum management: CEPT. 2001. "License Fees in the CEPT". CEPT (Link).
[183] ESPI, "ESPI2040: Space for Prosperity, Peace and Future Generations" (Link)

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Perspectives presented in this report are ESPI's viewpoints and not necessarily reflect the opinions of the individuals who served as reviewers or were interviewed as part of this research.

List of Interviewers & Reviewers	
Jennifer A. Manner	Senior Vice President, Regulatory Affairs, EchoStar
Matteo Cappella	Regulatory Affairs Specialist, Leaf Space
Frederico Di Vruno	Spectrum Manager, SKAO
Andrew Falle	Junior Fellow, Outer Space Institute
Véronique Glaude	Senior Radiocommunication Engineer, ITU
Alexandre Guerin	Director of Regulatory Affairs and Spectrum Management, Eutelsat
Dominic Hayes	Spectrum Management & International Relations, DG Defence Industry & Space, COM
Simon Molgat Laurin	Spacecraft Systems Engineer, Rocket Lab
Ewan Wright	Junior Fellow, Outer Space Institute
Franz Ziegelwanger	Director technical, Telecommunications and Postal Services Department, Ministry of Finance, Austria

The list of Interviewers & Reviewers reflects the diversity of actors involved in spectrum management. Additional informal interviews were conducted with representatives of the European Space Agency (ESA), national space agencies and spectrum authorities, as well as additional representatives of the private sector, NGO, and academia.

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Annex A: List of Abbreviations

Abbreviations	
3GPP	3rd Generation Partnership Project
AI	Agenda Item
ANFR	French National Frequencies Agency
API	Advance Publication Information
APT	Asia-Pacific Telecommunity
AR	Administrative Regulations
Arcep	Electronic Communications, Postal and Print Media Distribution Regulatory Authority
ATU	African Telecommunications Union
BEREC	Body of European Regulators for Electronic Communications
BiU	Bring into Use
BNetzA	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways
BR	Radiocommunication Bureau
BR IFIC	Radiocommunication Bureau's International Frequency Information Circular
BSS	Broadcasting Satellite Service
CBRS	Citizen's Band Radio Service
CEPT	European Conference of Postal and Telecommunications Administrations
COM	European Commission
CPM	Conference Preparatory Meeting
CR	Coordination procedures
CS	Constitution of the International Telecommunication Union,
CV	Convention of the International Telecommunication Union,
DBS	Direct Broadcast Services
DTH	Direct-to-home
EARC	Extraordinary Administrative Radio Conference
ECC	Electronic Communications Committee
EECC	European Electronic Communications Code
EESS	Earth Exploration-Satellite Service
EHF	Extremely high frequency
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
FCC	U.S Federal Communications Commission
FCFS	First Come, First Served
FSS	Fixed-satellite service
GEO	Geostationary Equatorial Orbit
GSO	Geostationary Orbit
IADC	Inter-Agency Space Debris Coordination Committee
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organisation

ICTs	Information and Communication Technologies
IMT	International Mobile Telecommunications
IRR	International Radio Regulations
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-R	ITU Radiocommunication sector
ITU-T	ITU Telecommunication Standardisation Sector
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MSS	Mobile Satellite Services
NFC	Near Field Communication
non-GSO	non-Geostationary
NSMS	National Spectrum Management Systems
OTT	Over-The-Top
PNT	Positioning, Navigation and Timing
PP	Plenipotentiary Conference
RA	Radiocommunication Assembly
RED	Radio Equipment Directive
RFID	Radio-Frequency Identification
RoP	Rules of Procedure
RR	Radio Regulations
RRB	Radio Regulations Board
RRC	Radio Regulations Committee
RSPG	Radio Spectrum Policy Group
RTOs	Regional Telecommunication Organisations
SDGs	Sustainable Development Goals
SG	ITU-R Study Groups
SHF	Super high frequency band
SIRRS	Satellite Interference Reporting and Resolution System
TCAM	Telecommunications Conformity Assessment and Market Surveillance
TFA	Table of Frequency Allocations
TR	International Telecommunication Regulations
TT&C	Telemetry, Tracking and Command
UAS	Universal access and service definition
UHF	Ultra-high frequency
UHTS	Ultra-High Throughput Satellites
VoD	Video on Demand
VHF	Very high frequency
VHTS	Very High Throughput Satellite
WMO	World Meteorological Organisation
WP	Working Parties

Annex B: International and European Regulatory Environment for Spectrum

The ITU Framework

ITU originally regulated the telegraph before the terrestrial radio services. The Agency first addressed the question of satellite communications in 1963 in conjunction with the launch into orbit of the first GSO satellite with commercial use through the Extraordinary Administrative Radio Conference (EARC-63, also called the Space Conference) to develop the basic administrative and technical regulations for the operation of space systems and allocate frequency bands for space radiocommunication purposes.[184]

This is reflected in the consensus reached in Article 33(2) of the ITU Convention of 1973.

> *"In using frequency bands for the space radio services Members shall bear in mind that* ***radio frequencies and the geostationary orbit are limited natural resources, that they must be used efficiently and economically*** *so that countries or group of countries may have equitable access to both in conformity with the provisions of the Radio Regulations according to their needs and the technical facilities at their disposal."*

Moreover, in 1985 and 1988, the World Administrative Radio Conference (WARC) on the use of GSO and the planning of the space services utilising it convened in Geneva had the task "*to reconcile the principle of guaranteed and equitable access with that of the efficient and economic use of two limited natural resources: GSO and the radio frequency spectrum.*"[185]

Thus, radio frequencies and any associated orbits, including the GSO orbital positions, are valuable assets and indispensable resources for satellite communications. As they are **limited natural resources,** they must be used **equitably, rationally, efficiently, and economically,** in conformity with provisions of the Radio Regulations (RR).

Several ITU Conferences and other relevant international events have led to the current ITU Legal Framework. **The Plenipotentiary Conference (PP)** is the supreme body of ITU and generally convenes every four years to determine the general policies of ITU and adopt the Financial Plan (Article 8 CS). In the interval between PPs, the Council meets annually to act as the governing body of ITU, on behalf of the PP. In particular, the Council adopts the agendas for administrative radio conferences (WRC and RRC).

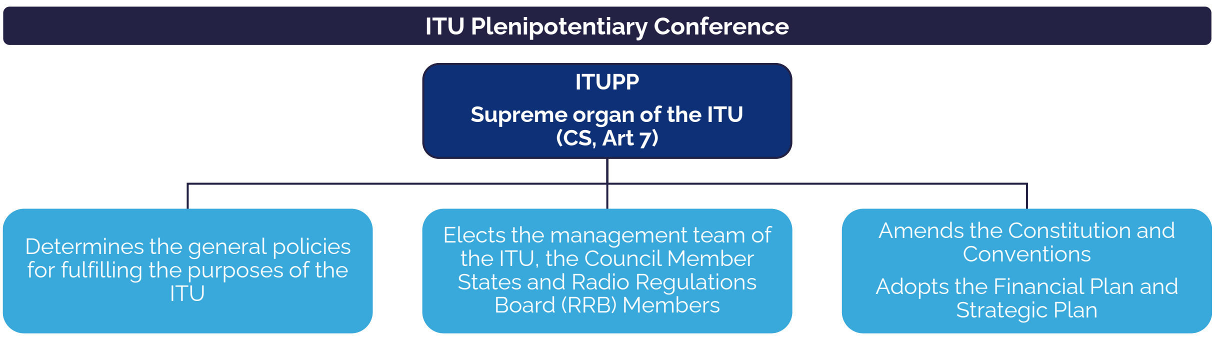

Figure 21: ITUPP Competencies (Source: ESPI, ITU)

[184] ITU. n.d. 'Radio Conference'. ITU (Link).
[185] ITU. 1985. 'World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it (1st session) (Geneva, 1985)'. History Portal of the ITU (Link).

Conferences have led to the adoption of several international treaties, which represent the key legal framework on which coordination mechanisms are based. They include:

- **Constitution of the International Telecommunication Union, (CS)**
- **Convention of the International Telecommunication Union, (CV)**
- Administrative Regulations (AR): International Telecommunication Regulations (TR) and International Radio Regulations (RR)

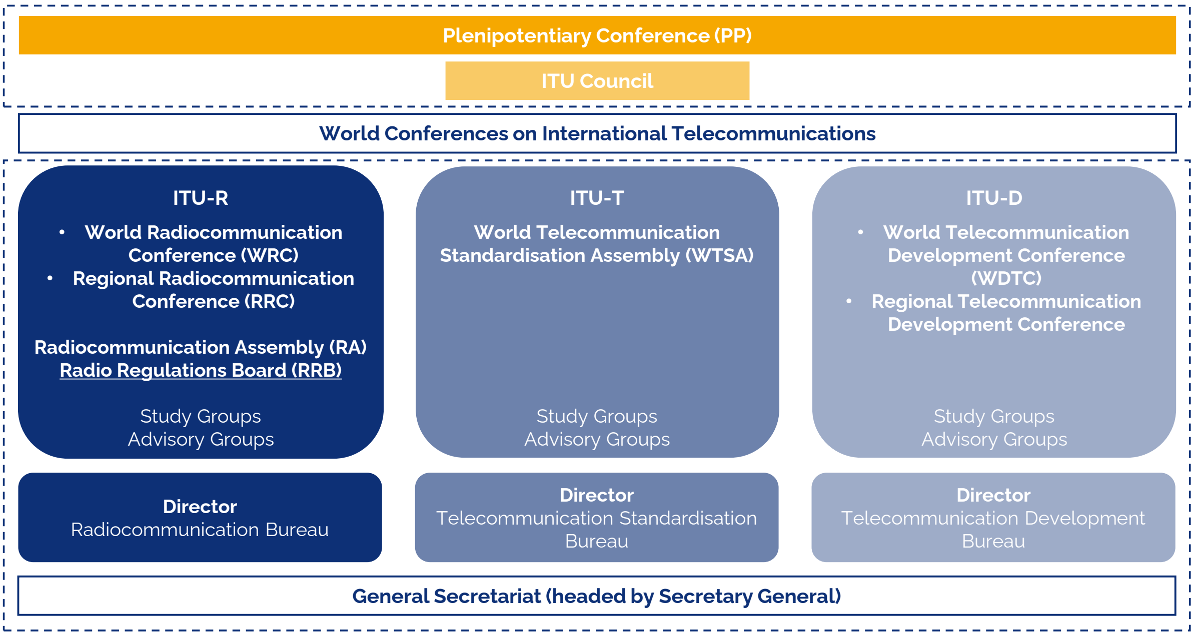

Figure 22: ITU Organigramme (Article 7 CS) (Source: ITU, ESPI)

ITU has three main areas of activity organised in three Sectors, with each of the three having its own unique characteristics and activities:

- **ITU Radiocommunication sector (ITU-R)** oversees the global radio-frequencies spectrum and satellite orbit management and coordination and develops and updates international regulations in the use of orbit/spectrum at the WRC and RRC.
- **ITU Telecommunication Standardisation Sector (ITU-T)** studies technical, operating, and tariff matters and adopts global standards for international telecommunications (recommendations).
- **ITU Telecommunication Development Sector (ITU-D)** facilitates and enhances telecommunications development by offering, organising, and coordinating technical cooperation and assistance activities in developing countries.

Each of the sector receive the support of two types of memberships: **Member States** and **Sector Members**, in addition to the participation of **Associates,** and **Academia** (Article 2 ITU CS).

ITU-R develops adopts the Radio Regulations (RR): they are updated every four years by the ITU WRCs. RR are a binding international treaty providing a framework for the use of radio-frequency spectrum and satellite orbit resources through a system of international coordination. Because of their binding nature, states must domestically apply their provisions, adopting adequate national legislation, in addition to special bilateral or multilateral arrangements.

Figure 23: Frequency Distribution

The need for frequency allocation, allotment and assignments activities are pursued at the ITU **World Radiocommunication Conference (WRC)** and **Regional Radiocommunication Conference (RRC)** level. The WRC may be associated the **Radiocommunication Assembly (RA),** which shall also normally be convened every three to four years.

The RA provide the necessary technical bases and respond to all requests for the work of the WRCs**.** It deals with and issue, as appropriate, recommendations on questions adopted pursuant to its own procedures or referred to it by the PP Conference, any other conference, the Council or the Radio Regulations Board.

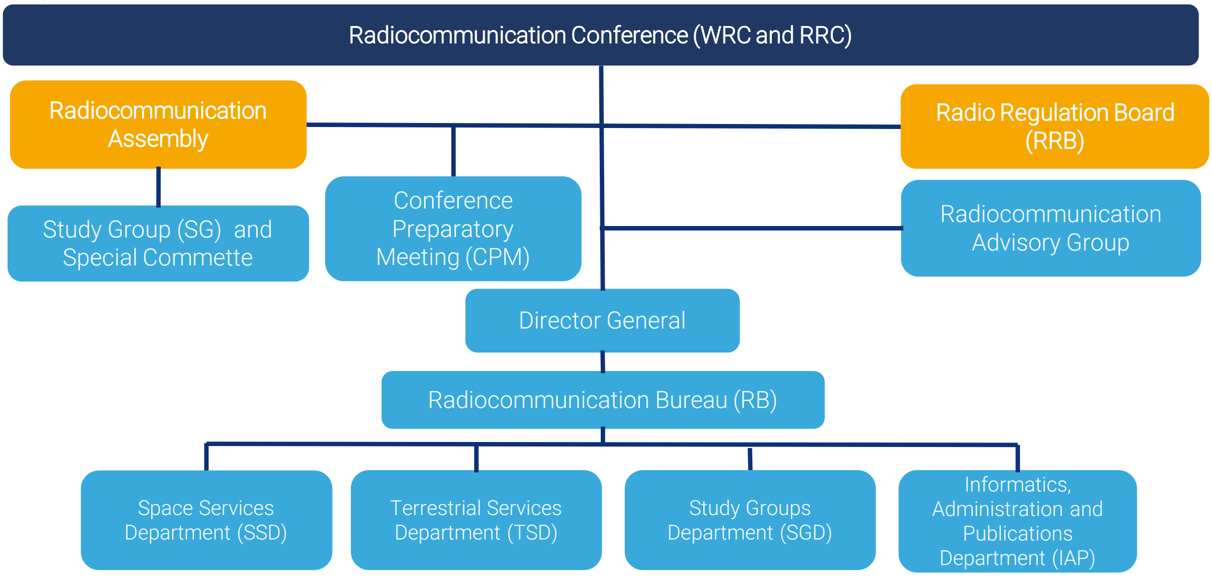

Figure 24: ITU-R organigramme (Source: ITU, ESP)

The WRC cycle can be represented as follow:

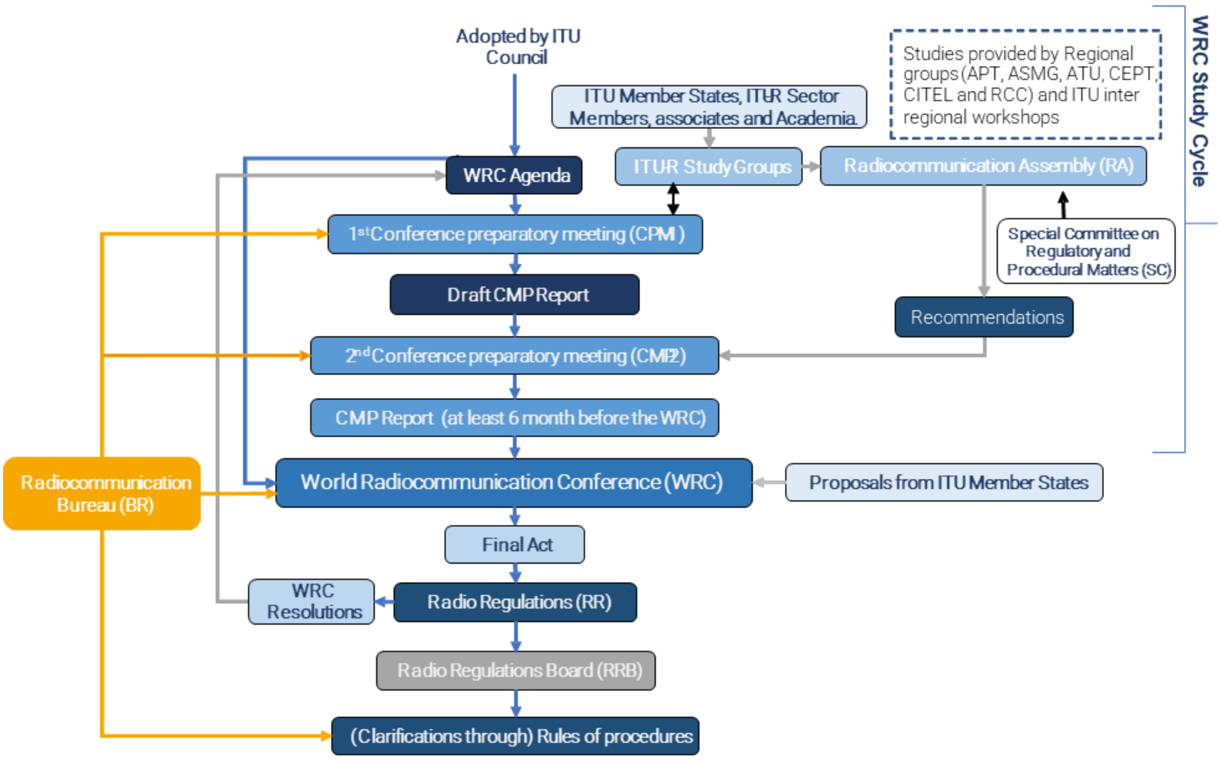

Figure 25: WRC Cycle (Source: ESPI, ITU)

The WRC (known until 1992 as World Administrative Radio Conferences - WARC) is a treaty-making conference, which convenes every 3 to 4 years, based on the Agenda recommended by the previous WRC and approved by Council.

It plays a key role in shaping the technical and regulatory framework for the provision of radiocommunication services in all countries. Among other tasks, it revises the Radio Regulations (including Appendices), adopts technical studies and work plans for a 6–10-year cycle, **adopts spectrum allocations**, adopts satellite regulatory procedures, **adopts allotment Plans** of the radio frequency spectrum, and reviews Rules of Procedures (RoP) and appeals from the Radio Regulations Board (RRB).[186]

The preparations for the conference include discussions at the level of ITU-R Study groups, the Conference Preparatory Meeting, as well as ITU inter-regional workshops, and within regional groups. Industry contributes to the Conference Preparatory Meeting (CPM) Report and participates in the WRC either as being part of Member State formal delegations or as an observer, whereby in the latter role industry may only submit information documents and provide advice but cannot submit proposals or participate in debates.

Proposals to WRCs are usually co-ordinated by countries through the relevant ITU-R Regional Groups:

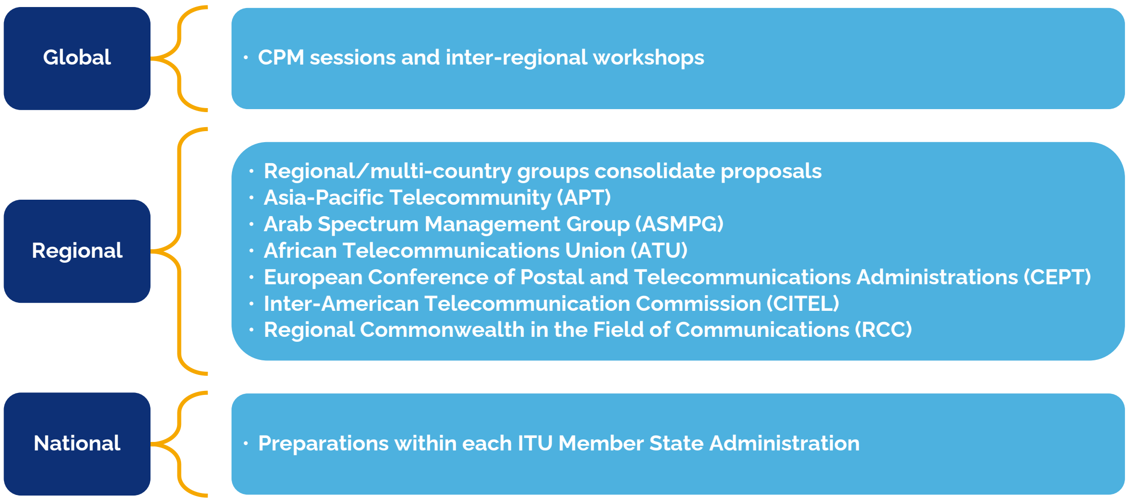

Figure 26: Preparation process for the WRC at the regional level (Source: ESPI, ITU)

The European Regulatory Environment for Spectrum

When focusing on the European level, several entities contribute to shaping policy and regulatory means on top of the national prerogatives. Firstly, the **European Conference of Postal and Telecommunications Administrations (CEPT),** the European regional body recognised by ITU, is similar to other organisations such as the Asia-Pacific Telecommunity (APT) or the African Telecommunications Union (ATU) for their respective regions. [187] The CEPT is a cooperative body that plays a crucial role in contributing to the harmonisation of spectrum use in Europe, especially by formulating common positions to ITU. Its Electronic Communications Committee (ECC) produces non-binding Decisions, Recommendations and Reports through a consensus decision-making process among its 46 members.

[186] The ITU Radiocommunication Bureau acts as the executive arm of the RRB.
[187] ETSI. 2016. 'The European regulatory environment for radio equipment and spectrum'. ETSI (Link).

The work of the ECC is supported by the Conference Preparatory Group, in charge of preparing the European Common Proposals for the WRC, as well as conducting studies on relevant matters.[188]

In addition, the **European Telecommunications Standards Institute (ETSI)** was created in 1988 under the auspices of CEPT to take responsibility for standardisation activities. Today, the Institute counts more than 750 members and is responsible for the release of globally applicable standards for ICTs, in parallel to technical reports on the technical, legal and economic aspects of new radio systems under standardisation. To maintain their strong links and ensure the consistency of ECC decisions with ETSI harmonised standards, the parties have signed a Memorandum of Understanding.[189]

Finally, the **European Commission** has positioned itself in the overall picture by developing a specific spectrum management policy and designing a framework for the regulation of some aspects of spectrum management. In particular, the Radio Spectrum Policy Programme Decision No. 243/2012/EU, which outlines the policy objectives of the EU on the matter: favouring innovation and investments trough flexible and efficient spectrum use, avoiding harmful interference, increasing the use of wireless data, promoting the secondary market (transfer and leasing) of spectrum rights, and contributing to the digital agenda for Europe. Regarding the regulatory aspects, a first complete set of Directives to regulate the telecom sector was adopted in 2002 (Telecom Package and Radio Spectrum Decision No. 676/2002/EC). The framework has undergone several reforms. The current framework builds on the European Electronic Communications Code (EECC), established in 2018 (Directive (EU) 2018/ 1972, repealing the previous 2002 Directives), and the Radio Equipment Directive (2014/53/EU - RED, repealing the previous R&TTE Directive No. 1999/5/EC). In particular, the EECC under Article 12 ensures the freedom to provide electronic communications networks and services based on a "general authorisation" regime, restating the freedom to provide services guaranteed by Article 56 of the TFEU. [190] Moreover, the EECC provides conditions that can be attached to authorisations, such as fees, interoperability, and accessibility in addition to allowing for the traceability and assignability of spectrum licenses, with member states facilitating transfers and leases of individual rights of use.[191] Satellite networks are explicitly included by the EECC as part of the electronic communications networks, in parallel to fixed and mobile networks, electricity cable systems, networks used for radio and television broadcasting and cable television networks.[192] Moreover, when describing the procedure for limiting the number of rights of use to be granted for radio spectrum (Art. 53), the EECC specifies that these limits "shall be without prejudice to any applicable international agreements relating to the use of radio spectrum (notably the ITU RR) and satellite coordination."

The policy and regulatory activity of the Commission is then supported by several bodies:

- The **Radio Spectrum Policy Group (RSPG)**, under DG CNECT, is an advisory body to the Commission and other EU institutions in parallel also promoting effective and efficient management of electronic communications networks and services, including non-EU countries' participation (Decision No. 2002/622/EC).[193] The RSPG's remit has been significantly expanded by the EECC Directive in 2018 and was finally confirmed in 2019 (Decision No. 219/4147, repealing the 2002 Decision).[194]

[188] ECC. 2023. 'Status of CEPT Preparation for WRC-23 / RA-23'. ECC CEPT (Link).
[189] ETSI. 2016. 'The European regulatory environment for radio equipment and spectrum'. ETSI (Link).
[190] See Art. 2 (22) EECC for the definition of general authorisation in Directive (EU) 2018/1972. EUR-Lex (Link).
[191] A. Baudequin, et al. 2022. 'In brief: telecoms regulation in European Union'. Lexology (Link).
[192] See Article 2 (1), Definitions in 'Directive (EU) 2018/1972 of 11 December 2018'. EUR-Lex (Link).
[193] COM. 2023. 'Radio Spectrum Policy Group. RSPG23-016 FINAL', COM (Link).
[194] COM. 2023. 'Radio Spectrum Policy Group (E01384)'. COM (Link).

- The **Body of European Regulators for Electronic Communications (BEREC)** is an expert body to promote an effective telecom internal market and ensures the implementation of the EU regulatory framework for telecommunications, assisting and advising both EU institutions and national regulatory authorities (EC 1211/2009 as part of the Telecom Reform Package). It is complemented by the BEREC Office, an EU agency established by the EECC in 2018.[195]
- The **Radio Spectrum Committee** is a group of experts from EU member states, chaired by the Commission, predominantly conducting comitology activities (Directive No. 676/2002/EC). [196]
- The **Telecommunications Conformity Assessment and Market Surveillance (TCAM),** under DG GROW, assists the Commission in the preparation of the standardisation requests for the development of harmonised standards.
- The **Administrative Cooperation Group (ADCO RED)** gathers the Member States' surveillance authorities in charge of ensuring that the equipment placed on the market is compliant with the technical conditions for spectrum use set by the RED Directive.

COM interacts significantly with both the CEPT ECC and ETSI. ETSI is recognised by the Commission as the European Standards Organisation (Regulation No. 1025/2012).[197] Also, while EU Decisions prevail on the ECC Decision, especially for the non-binding nature of these last ones, CEPT releases its Reports upon mandate issued by the Commission (Directive the 676/2002, Art. 4(2)).[198]

[195] BEREC. n.d. 'Mission'. BEREC (Link).
[196] COM. n.d. 'The Radio Spectrum Committee'. COM (Link). See also COM. n.d. 'Comitology'. COM (Link).
[197] ETSI. 2016. 'European regulatory environment for radio equipment & spectrum. An introduction. Version 2. 1(Link).
[198] COM. n.d. 'Radio Spectrum CEPT Mandates'. COM (Link).

ANNEX C: STUDY GROUPS AND AGENDA ITEMS FOR THE WRC-23

ITU-R Study Groups

The ITU-R Study Groups develop the technical bases for decisions taken at the WRCs and develop global standards (Recommendations), Reports and Handbooks on radiocommunication matters. An overview of the ITU Study Group is presented below.[199]

SG1 - Spectrum management		Spectrum management principles and techniques, general principles of sharing, spectrum monitoring, long-term strategies for spectrum utilisation, economic approaches to national spectrum management, automated techniques and assistance to developing countries in cooperation with the Telecommunication Development Sector.
	WP 1A - Spectrum engineering techniques	Spectrum engineering techniques, including unwanted emissions, frequency tolerance, technical aspects of sharing, spectrum engineering, computer programs, technical definitions, Earth-station coordination areas and technical spectrum efficiency.
	WP 1B - Spectrum management methodologies and economic strategies	Spectrum management fundamentals, including economic strategies, spectrum management methodology, national spectrum management organisation, national and international regulatory framework, alternative approaches, flexible allocations and long-term strategies for planning.
	WP 1C - Spectrum monitoring	Spectrum monitoring, including the development of techniques for observing the use of the spectrum, measurements techniques, inspection of radio stations, identification of emissions and location of interference sources.
SG3 - Radiowave propagation		Propagation of radio waves in ionised and non-ionised media and the characteristics of radio noise, for the purpose of improving radiocommunication systems.
	WP 3J - Propagation fundamentals	Provides information and develops models describing the fundamental principles and mechanisms of radiowave propagation in non-ionised media. Such material is used as the basis of propagation prediction methods developed by the other Working Parties. Recognising the natural variability of the propagation medium, WP 3J prepares texts describing the statistical laws relevant to propagation behaviour and the means of expressing the temporal and spatial variability of propagation data

[199] ITU. n.d. 'Radiocommunication Study Groups'. ITU (Link).

	WP 3K - Point-to-area propagation	Responsible for developing prediction methods for terrestrial point-to-area propagation paths. In the main, these are associated with terrestrial broadcasting and mobile services, short-range indoor and outdoor communication systems (e.g., radio local area networks, RLAN), and with point-to-multipoint wireless access systems.
	WP 3L - Ionospheric propagation and radio noise	Studies all aspects of radiowave propagation in and through the ionosphere. Recommendations are maintained describing, in mathematical terms, a reference model of ionospheric characteristics and maximum usable frequencies associated with the various ionospheric layers. Short-term and long-term ionospheric forecasting, with guidance on the use of ionospheric indices, is addressed.
	WP 3M - Point-to-point and Earth-space propagation	Addresses radiowave propagation over point-to-point terrestrial paths and Earth-space paths, both for wanted and unwanted signals. For terrestrial paths, prediction methods are developed for both line-of-sight and over-the-horizon links, taking into account the possible mechanisms that can give rise to fading and distortion of the wanted signal. The resulting predictions, generally expressed in terms of a statistical distribution of propagation loss or outage, provide vital information for terrestrial link planning in the fixed service (FS).
SG4 - Satellite services		Systems and networks for the fixed-satellite service, mobile-satellite service, broadcasting-satellite service and radiodetermination-satellite service.
	WP 4A - Efficient orbit/spectrum utilisation for the FSS and BSS	Orbit/spectrum efficiency, interference and coordination and related aspects for FSS and BSS. Its work has significant relevance to the preparatory work for World Radiocommunication Conferences
	WP 4B - Systems, air interfaces, performance and availability objectives for FSS, BSS and MSS, including IP-based applications and satellite news gathering (SNG)	Carries out studies on performance, availability, air interfaces and earth-station equipment of satellite systems in the FSS, BSS and MSS. This group has paid particular attention to the studies of Internet Protocol (IP)-related system aspects and performance and has developed new and revised Recommendations and Reports on IP over satellite to meet the growing need for satellite links to carry IP traffic. This group has close cooperation with the ITU Telecommunication Standardisation Sector.
	WP 4C – Efficient orbit/spectrum utilisation for the mobile-satellite service (MSS) and the radiodetermination-satellite service (RDSS)*	Studies conducted within Working Party 4C are aiming at a more efficient use of the orbit/spectrum resources by MSS and RDSS systems. This includes analysing various interference situations between such systems but also with systems operating in other radiocommunication services, developing coordination methodologies, describing the potential use of MSS and RDSS systems for specific purposes like emergency situations, maritime or aeronautical telecommunications, time distribution, etc.
SG5 - Terrestrial services		Systems and networks for fixed, mobile, radiodetermination, amateur and amateur-satellite services.
	WP 5A - Land mobile service excluding IMT; amateur and amateur-satellite service	Responsible for studies related to the land mobile service, excluding IMT and including wireless access in the fixed service, and is also responsible for studies related to the amateur and amateur-satellite services.

	WP 5B - Maritime mobile service including the Global Maritime Distress and Safety System (GMDSS); the aeronautical mobile service and the radiodetermination service	Responsible for studies related to the maritime mobile service, including the Global Maritime Distress and Safety System (GMDSS), the aeronautical mobile service and the radiodetermination service, including both radiolocation and radionavigation services. It studies communication systems for the maritime mobile and aeronautical mobile services and radar and radiolocation systems for the radiodetermination service.
	WP 5C - Fixed wireless systems; HF systems in the fixed and land mobile services	Responsible for studies related to fixed wireless systems and HF systems in the fixed and land mobile services. It studies performance and availability objectives, interference criteria, RF channel/block arrangements, system characteristics and sharing feasibility. (Note that for fixed wireless access (FWA) systems, work related to public access systems for potentially large deployment coverage is carried out in WP 5A.)
	WP 5D - IMT Systems	Responsible for the overall radio system aspects of the terrestrial component of International Mobile Telecommunications (IMT) systems, comprising the current IMT-2000, IMT-Advanced and IMT-2020 as well as IMT for 2030 and beyond.
SG6 - Broadcasting service		Radiocommunication broadcasting, including vision, sound, multimedia and data services principally intended for delivery to the general public.
	WP 6A WP 6B WP 6C	Current work items
SG7 - Science services		Systems for space operation, space research, Earth exploration and meteorology, including the related use of links in the inter-satellite service. Systems for remote sensing, including passive and active sensing systems, operating on both ground-based and space-based platforms. Radio astronomy and radar astronomy. Dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a worldwide basis.
	WP 7A - Time signals and frequency standard emissions	Covers standard frequency and time signal services, both terrestrial and satellite. Its scope includes the dissemination, reception and exchange of standard frequency and time signals and coordination of these services, including the application of satellite techniques on a worldwide basis.
	WP 7B - Space radiocommunication applications	Responsible for the transmission and reception of telecommand, tracking and telemetry data for space operation, space research, Earth exploration-satellite, and meteorological satellite services. It studies communication systems for use with manned and unmanned spacecraft, communication links between planetary bodies and the use of data relay satellites.
	WP 7C - Remote sensing systems	Covers remote sensing applications in the Earth exploration-satellite service (EESS), both active and passive, systems of MetAids service, as well as space research sensors, including planetary sensors.
	WP 7D - Radio astronomy	Covers the radio astronomy service. Its scope includes radio astronomy and radar astronomy sensors, both Earth-based and space-based, including space very long baseline interferometry (VLBI)

The ITU WRC-23 Agenda Items

The WRC-23 has 10 Agenda Items, with 19 topics under Agenda item 1, 9 topics under Agenda Items 7 and 3 topics under Agenda Items 9. The WRC-23 agenda is contained in Resolution 811 (WRC-19).[200] A comprehensive list is provided below.[201]

WRC-23 Agenda Item	Title	WRC Resolution	Responsible Working Party & Study Group	Chapters of the draft CPM Report
1	On the basis of proposals from administrations, taking account of the results of the WRC-19 and the Report of the CPM, and with due regard to the requirements of existing and future services in the frequency bands under consideration, to consider and take appropriate action in respect of the following items:	Res.223 (Rev.WRC-19)	WP 5B (1) WP 5D (1)	Chapter 1
1.1	to consider, based on the results of the ITU R studies, possible measures to address, in the frequency band 4 800-4 990 MHz, protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories, and to review the pfd criteria in No. 5.441B in accordance with Resolution 223);	Res.245 (WRC-19)	WP 5D	Chapter 1
1.2	to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for IMT, including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 245 (WRC-19);	Res.246 (WRC-19)	WP 5A	Chapter 1
1.3	to consider primary allocation of the band 3 600-3 800 MHz to mobile service within Region 1 and take appropriate regulatory actions, in accordance with Resolution 246 (WRC-19);	Res.247 (WRC-19)	WP 5D	Chapter 1
1.4	to consider, in accordance with Resolution 247 (WRC-19), the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level;	Res.235 (WRC-15)	TG 6/1 (2)	Chapter 1
1.5	to review the spectrum use and spectrum needs of existing services in the frequency band 470-960 MHz in Region 1 and consider possible regulatory actions in the frequency band 470-694 MHz in Region 1 on the basis of the review in accordance with Resolution 235 (WRC-15);	Res.772 (WRC-19)	WP 5B (3)	Chapter 1
1.6	to consider, in accordance with Resolution 772 (WRC-19), regulatory provisions to facilitate radiocommunications for sub-orbital vehicles;	Res.428 (WRC-19)	WP 5B (3)	Chapter 2
1.7	to consider a new aeronautical mobile-satellite (R) service (AMS(R)S) allocation in accordance with Resolution 428 (WRC-19) for both the Earth-to-space and space-to-Earth directions of aeronautical VHF communications in all or part of the frequency band 117.975-137 MHz, while preventing any undue constraints on existing VHF systems operating in the AM(R)S, the ARNS, and in adjacent frequency bands;	Res.171 (WRC-19) - Res.155 (Rev.WRC-19)	WP 5B (3)	Chapter 2
1.8	to consider, on the basis of ITU R studies in accordance with Resolution 171 (WRC-19), appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution 155 (Rev.WRC-19) and No. 5.484B to accommodate the use of fixed-satellite service (FSS) networks by control and non-payload communications of unmanned aircraft systems;	Res.429 (WRC-19)	WP 5B	Chapter 2
1.9	to review Appendix 27 of the Radio Regulations and consider appropriate regulatory actions and updates based on ITU R studies, in order to accommodate digital technologies for commercial aviation safety-of-life applications in	Res.430 (WRC-19)	WP 5B	Chapter 2

[200] ITU. 2019. 'Resolution 811'. ITU (Link).
[201] ITU. n.d. 'WRC-23 Agenda Items'. ITU (Link).

	existing HF bands allocated to the aeronautical mobile (route) service and ensure coexistence of current HF systems alongside modernised HF systems, in accordance with Resolution 429 (WRC-19);			
1.10	to conduct studies on spectrum needs, coexistence with radiocommunication services and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications, in accordance with Resolution 430 (WRC-19);	Res.361 (Rev.WRC-19)	WP 5B (4)	Chapter 2
1.11	to consider possible regulatory actions to support the modernisation of the Global Maritime Distress and Safety System and the implementation of e navigation, in accordance with Resolution 361 (Rev.WRC-19);	Res.656 (Rev.WRC-19)	WP 7C	Chapter 2
1.12	to conduct, and complete in time for the WRC-23, studies for a possible new secondary allocation to the Earth exploration-satellite (active) service for spaceborne radar sounders within the range of frequencies around 45 MHz, taking into account the protection of incumbent services, including in adjacent bands, in accordance with Resolution 656 (Rev.WRC-19);	Res.661 (WRC-19)	WP 7B	Chapter 3
1.13	to consider a possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service, in accordance with Resolution 661 (WRC-19);	Res.662 (WRC-19)	WP 7C	Chapter 3
1.14	to review and consider possible adjustments of the existing or possible new primary frequency allocations to EESS (passive) in the frequency range 231.5-252 GHz, to ensure alignment with more up-to-date remote-sensing observation requirements, in accordance with Resolution 662 (WRC-19);	Res.172 (WRC-19)	WP 4A	Chapter 3
1.15	to harmonise the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally, in accordance with Resolution 172 (WRC-19);	Res.173 (WRC-19)	WP 4A	Chapter 4
1.16	to study and develop technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz and 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-GSO FSS earth stations in motion, while ensuring due protection of existing services in those frequency bands, in accordance with Resolution 173 (WRC-19);	Res.773 (WRC-19)	WP 4A	Chapter 4
1.17	to determine and carry out, on the basis of the ITU R studies in accordance with Resolution 773 (WRC-19), the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate;	Res.248 (WRC-19)	WP 4C	Chapter 4
1.18	to consider studies relating to spectrum needs and potential new allocations to the mobile-satellite service for future development of narrowband mobile-satellite systems, in accordance with Resolution 248 (WRC-19);	Res.174 (WRC-19)	WP 4A	Chapter 4
1.19	to consider a new primary allocation to the fixed-satellite service in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2, while protecting existing primary services in the band, in accordance with Resolution 174 (WRC-19);	Res.27 (Rev.WRC-19)	CPM23-2	Chapter 4
2	to examine the revised ITU R Recommendations incorporated by reference in the Radio Regulations communicated by the Radiocommunication Assembly, in accordance with further resolves of Resolution 27 (Rev.WRC-19), and to decide whether or not to update the corresponding references in the Radio Regulations, in accordance with the principles contained in resolves of that Resolution;	-	-	Chapter 5
3	to consider such consequential changes and amendments to the Radio Regulations as may be necessitated by the decisions of the conference;	Res.95 (Rev.WRC-19)	CPM23-2	-
4	in accordance with Resolution 95 (Rev.WRC-19), to review the Resolutions and Recommendations of previous conferences with a view to their possible revision, replacement or abrogation;	-	-	Chapter 5
5	to review, and take appropriate action on, the Report from the Radiocommunication Assembly submitted in accordance with Nos. 135 and 136 of the Convention;	-	-	-
6	to identify those items requiring urgent action by the radiocommunication study groups in preparation for the next world radiocommunication conference;	Res.86 (Rev.WRC-07)	WP 4A	-
7	to consider possible changes, in response to Resolution 86 (Rev. Marrakesh, 2002) of the Plenipotentiary Conference, on advance publication, coordination, notification and recording procedures for frequency assignments pertaining	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4

		to satellite networks, in accordance with Resolution 86 (Rev.WRC-07), in order to facilitate the rational, efficient and economical use of radio frequencies and any associated orbits, including the geostationary-satellite orbit;			
	A	Tolerances for certain orbital characteristics of non-GSO space stations in the FSS, BSS or MSS	Res. 86 (Rev.WRC-07)	WP 4A	Chapter 4
	B	Non-GSO bringing into use post-milestone procedure	Res. 86 (Rev.WRC-07)	WP 4A	Chapter 4
	C	Protection of geostationary satellite networks in the mobile-satellite service operating in the 7/8 GHz and 20/30 GHz bands from emissions of non-geostationary satellite systems operating in the same frequency bands and identical directions	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	D	Issues for which consensus was achieved in ITU-R (See below)	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	D1	Modifications to Appendix 1 to Annex 4 of RR Appendix 30B	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	D2	New RR Appendix 4 parameters for Recommendation ITU-R S.1503 updates	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	D3	BR reminders for BIU and BBIU	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	E	RR Appendix 30B improved procedures for new Member States	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	F	Excluding uplink service area in RR Appendix 30A for Regions 1 and 3 and RR Appendix 30B	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	G	Revisions to Resolution 770 (WRC-19) to allow its implementation	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	H	Enhanced protection of RR Appendices 30/30A in Regions 1 and 3 and RR Appendix 30B	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	I	Special agreements under RR Appendix 30B	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	J	Modifications to Resolution 76 (Rev.WRC-15)	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
	K	Modification to Resolution 553 (Rev.WRC-15) to remove certain restrictions that prevent administrations from taking effective advantage of the Resolution	Res.86 (Rev.WRC-07)	WP 4A	Chapter 4
8		to consider and take appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes, if no longer required, taking into account Resolution 26 (Rev.WRC-19);	Res.86 (Rev.WRC-07)	WP 4A	-
9		to consider and approve the Report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Convention;	Res.26 (Rev.WRC-19)	-	-
	9.1	on the activities of the Radiocommunication Sector since the WRC-19:	-	-	-
	a)	In accordance with Resolution 657 (Rev.WRC-19), review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services;	Res.657 (Rev.WRC-19)	WP 7C	Chapter 5
	b)	Review of the amateur service and the amateur-satellite service allocations in the frequency band 1 240 1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite (space-to-Earth) service operating in the same band in accordance with Resolution 774 (WRC-19);	Res.774 (WRC-19)	WP 5A (5)	Chapter 5
	c)	Study the use of International Mobile Telecommunication systems for fixed wireless broadband in the frequency bands allocated to the fixed services on primary basis, in accordance with Resolution 175 (WRC-19);	Res.175 (WRC-19)	WP 5A (6) WP 5C (6)	Chapter 5
	d)	Protection of EESS (passive) in the frequency band 36-37 GHz from non-GSO FSS space stations;	Doc. 573 (WRC-19)	WP 7C	Chapter 5
	9.2	on any difficulties or inconsistencies encountered in the application of the Radio Regulations; and (This agenda sub-item is strictly limited to the Report of the Director on any difficulties or inconsistencies encountered in the on any difficulties or inconsistencies encountered in the application of the Radio Regulations; and (This agenda sub-item is strictly limited to the Report of the Director on any difficulties or inconsistencies encountered in the application of the Radio Regulations and the comments from administrations. Administrations are invited to inform the Director of the Radiocommunication Bureau of any difficulties or inconsistencies encountered in the Radio Regulations.)	-	-	-
	9.3	on action in response to Resolution 80 (Rev.WRC-07);	Res.80 (Rev.WRC-07	-	-
10		to recommend to the Council items for inclusion in the agenda for the next WRC, and items for the preliminary agenda of future conferences, in accordance with Article 7 of the Convention and Resolution 804 (Rev.WRC-19);	Res.804 (Rev.WRC-19) - Res. 812 (WRC-19)	See studies on the WRC-27 pr	-

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