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Aeronautical Items Relevant to the World Radiocommunication Conference 2027

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ABSTRACT

During the World Radiocommunication Conference to be held in 2027 (WRC-27), resolutions or agenda items that could significantly impact the operation of existing services, including aeronautical ones, will be analyzed. Among these items, those that could directly or indirectly affect aviation, in the view of the International Civil Aviation Organization (ICAO), include new frequency allocations for International Mobile Telecommunications (IMT), new allocation for aeronautical mobile service (route), new allocations for the mobile satellite service, development of telecommunications on the Moon, and new allocations for space research and Earth exploration satellite services. This study offers a comprehensive analysis of the spectrum management framework, with a particular focus on key WRC-27 agenda items affecting civil aviation. By examining the perspectives of ICAO, regulatory bodies, and industry stakeholders, it identifies potential risks to aeronautical services, their implications, and possible mitigation strategies, emphasizing the crucial role of regulatory agencies in safeguarding critical communication systems. As a valuable resource for decision-makers and researchers, this study enhances the understanding of spectrum allocation challenges and informs strategies for effective spectrum management.

Keywords: Mobile communication systems; Aircraft communication; Civil aviation.

INTRODUCTION

The demand for access to segments of the frequency spectrum reflects the evolution of technologies and the increase in applications that use more and more bandwidth. Therefore, the allocation and coordination of spectrum present a significant challenge, as they must find equilibrium between efficiency and equitable decisions (ITU 2014b). Thus, efficient spectrum management is essential, defining the allocations of radiocommunication services, their technical specifications, and determining which systems and technologies are able to operate in a given country. Spectrum management includes, among others: the protection of frequencies used by critical services, preventing harmful interference; the identification of opportunities to maximize efficiency, allowing the development and implementation of new technologies within flexible structures; and the reduction of the costs of telecommunications equipment, allowing society to access them on an equal basis (ITU 2022; Xiao *et al.* 2005).

One of the biggest challenges in allocating and coordinating radio frequency spectrum is the complexity of balancing technological innovation with risk and interference mitigation (ITU-R 2001). The main difficulty lies in the practical impossibility of achieving a zero-risk solution, thus requiring constant weighing of conflicting risks. Three trade-offs can basically be defined in this context: (1) The dilemma between risk and innovation can be exemplified by the regulation of the use of electronic

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devices on aircraft. The difference in approaches between regulators such as the U.S. Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) highlights the difficulties of international harmonization, creating uncertainties that can restrict innovation in technologies such as cognitive radio and spectrum trading (Knoblock *et al.* 2023). The challenge lies in balancing the benefits of connectivity with the risks to security; (2) The definition of interference thresholds is complex, as it depends on the choice of propagation models and scenarios, influencing the results. Therefore, the "no observed effect level" involves both technical and political decisions, affecting the risk assessment. The probability of interference, as recommended by the International Telecommunication Union (ITU), is challenging to apply. More advanced models improve the assessment and coexistence of systems, but some level of interference is necessary for the adoption of new technologies; (3) Spectrum management involves two kinds of errors: Type I (rejecting innovations) and Type II (allowing harmful practices), where minimizing one increases the other. This requires choosing between *ex-ante* (preventive) and *ex-post* (later intervention) approaches. The choice is indicative of the priorities of the relevant decision-makers and has a significant impact on innovation and efficient spectrum use. Achieving an equilibrium among these perspectives is imperative for the effective implementation of policy. In short, these trade-offs highlight the need for interdisciplinary approaches that transcend linear regulatory models, favoring strategies that integrate technological, economic, political, and sociocultural dimensions (Carvalho 2019; Mazar 2016). In this sense, spectrum harmonization supports standardized – and streamlined – manufacturing of network equipment and wireless devices, resulting in more rapid deployment, improved performance of the network, and lower consumer costs (Javed *et al.* 2024).

Aeronautical and other telecommunications services are competing for the scarce spectrum resource, requiring policies that balance the demands of these sectors. This requires overcoming technological and regulatory constraints and adapting to the rapidly evolving radio frequency environment, while complying with ITU Radio Regulations (RR) (ITU-R 2024). Therefore, it is essential to implement incentives and policy changes to promote this technological progress, ensuring that aviation continues to have access to this vital resource at a low cost (Eurocontrol 2022). The aviation industry plays a crucial role in the global economy, supporting connectivity, commerce, and tourism. In addition to technical aspects, economic factors are essential to ensuring the safety and efficiency of airspace operations.

In this way, there must be synergy between space, aviation, terrestrial telecommunications, and other services so that all existing systems and those arising from new technologies can operate safely to meet the society's needs. Although there is national independence in granting spectrum usage authorization, regulatory bodies rely on international agreements and decisions, as frequency bands can be allocated and assigned to various services. All applications must operate in harmony to mitigate the possibility of interference; therefore, it is essential that regulations be defined to support sharing and compatibility between telecommunications systems. Sharing allows the simultaneous and cooperative use of spectrum by different services (primary, non-exclusive, or secondary) in a specific area. Several techniques can be used to achieve the best efficiency in spectrum usage (GSMA 2024a; b; Kour *et al.* 2018; Nguyen 2024).

In this scenario, the primary function of the ITU is to regulate the use of radio frequencies. The objective of this regulatory framework is to prevent harmful interference between radiocommunication stations. The ITU is responsible for coordinating the use of the spectrum at international borders. However, the responsibility for implementing these activities at the national level lies with the member states and their respective regulatory agencies. In Brazil, the Agência Nacional de Telecomunicações (ANATEL) serves as the national representative to the ITU (ANATEL 2024; Marzioli *et al.* 2024). To ensure operations that minimize the likelihood of interference, the ITU RR defines mechanisms such as frequency allocation, coordination in the sharing of orbits and spectrum, power limits, and monitoring of radiocommunication systems. To undertake ITU activities, the Radiocommunication Bureau seeks to ensure, amongst other things, the rational, equitable, efficient, and economical use of the radio spectrum pursuant to the radio regulations, constitution, convention, procedures, and recommendations. In addition, it is important to highlight the relevance of the Final Acts of the WRC and the technical preparations of the Study Groups (SG) to keep the RR updated after each WRC and the Plenipotentiary Meeting (Marcus and Ghosh 2024; Marzioli *et al.* 2024).

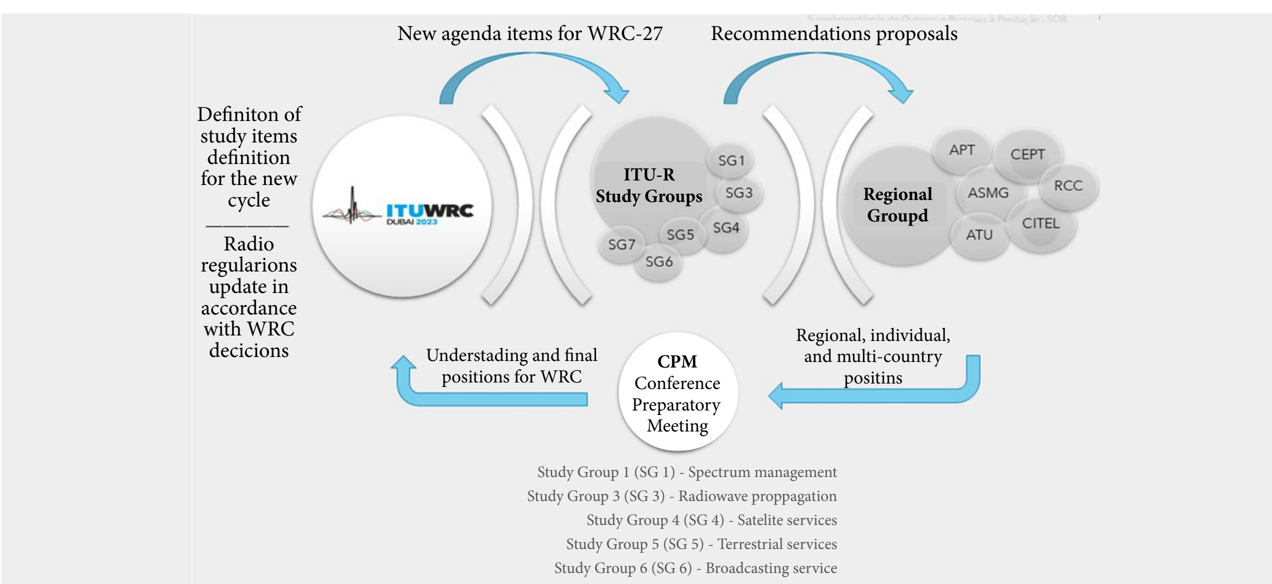
Regulation is, therefore, one of the main tools to ensure the equitable use and management of spectrum, and can therefore have a strong impact on the development of new technologies and the protection of existing ones. National regulators must update spectrum management plans to meet growing demands and promote connectivity and social goals, in addition to simplifying the allocation process with low complexity coordination and maintaining an up-to-date the frequency bands registration list (ITU 2022; 2024).

WRC takes place every 3 or 4 years and, in the period immediately preceding them, the Radiocommunication Assembly (RA) is held, with the main objective of dealing with the structure, scope and study program of the SG of the ITU Radiocommunication Sector (ITU-R). WRC centralizes global discussions on telecommunications and establishes procedures and decisions that may have an impact on the interests of member countries, becoming an international treaty. As such, the conferences are highly relevant, serving as a point of convergence for studies, negotiations and decisions in the years leading up to them (ANATEL 2023).

Also, within the scope of WRC, the activities of the Radio Regulations Board and the Radiocommunication Bureau of ITU-R are defined, in addition to the study questions for the RA and its SGs. The technical and regulatory aspects of the topics to be addressed are analyzed by the SGs during the study cycle, based on the work of the 1st Session of the Preparatory Meeting (CPM-1). The specific committees prepare reports for the 2nd Session (CPM-2), held only 6 months before the WRC. Based on the analyses and contributions of the SGs, administrations, and other sources, a final report is produced, which supports the work of WRC (ANATEL 2023). It is also important to highlight the importance of the regional SG, whose positions are presented in the CPM-2. The main regional groups are:

- APT – Asia-Pacific Telecommunity;
- ASMG – Arab Spectrum Management Group;
- ATU – African Telecommunications Union;
- CEPT – European Conference of Postal and Telecommunications Administrations;
- CITEL – Inter-American Telecommunication Commission;
- RCC – Regional Commonwealth in the Field of Communications.

The regional group to which Brazil belongs is CITEL, and Fig. 1 illustrates the mechanism of the ITU study cycle (ANATEL 2023; CITEL 2024).



Source: Elaborated by the authors.

Figure 1. ITU study cycle mechanism.

Looking at Fig. 1 it is possible to say that the WRC possesses an organizational process and a cycle of development of its activity (ANATEL 2023; GSMA 2024b; WRC 2025). In the first years of preparation for a conference, the focus is on the organization of studies and the definition of functions in the ITU-R. It has the following main elements:

1. Formalizing the next WRC agenda: definition of the WRC agenda items WRC happens in a preceding conference. In the first year of the subsequent cycle, however, the ITU Council looks at and authorizes the main issues to be examined.
2. Allocation of agenda items to ITU-R SG: The agenda items are allocated to a SG and one or more ITU-R working parties (WP), which will initiate discussion on the studies to be conducted.
3. CPM-1: Is held a few months after the latest WRC, aiming to develop a structured work plan for the upcoming years.
4. Involvement of regional organizations: at this point, regional organizational meetings begin taking cue from the WRC agenda; thus, such nations begin preparations to conduct determination of regional positions in the future. Likewise, similar meetings on the agenda topics are also organized by other organizations of concern such as the International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO) to provide their views accordingly.

In general, a bit more than 2 years after the studies have been initiated, a CPM report draft shall be drafted on the basis of the initial results of the studies and, finally, on the recommendation of approaches to meet the agenda item.

The purpose of the WRC is, therefore, to review the RR, which governs the use of the radio spectrum and satellite orbits. The reviews are based on an agenda (or agenda items) set by the ITU Council, with consideration of recommendations from previous conferences (ESPI 2024; GSMA 2017; WRC 2025).

Following, Table 1 lists the WRC-27 agenda items to the respective WPs responsible and to recommendations from the previous conference that served as a basis for these items (ITU 2024b).

In a general way, during the preparation for WRC-27, new frequency allocations and regulatory actions will be analyzed that could benefit several sectors. On the other hand, these initiatives could cause interference with systems already in operation, such as aeronautical systems.

Table 1. WRC-27 agenda items.

Agenda item	Responsible working group	Resolution
1.1	4A	Res. 176 (Rev.WRC-23)
1.2		Res. 129 (WRC-23)
1.3		Res. 130 (WRC-23)
1.4		Res. 726 (WRC-23)
1.5		Res. 14 (WRC-23)
1.6		Res. 131 (WRC-23)
1.7	5D	Res.256 (WRC-23)
1.8	5B	Res.663 (Rev.WRC-23)
1.9		Res.411 (WRC-23)
1.10	5C	Res.775 (Rev.WRC-23)
1.11	4C	Res.249 (Rev. WRC-23)
1.12		Res.252 (WRC-23)
1.13		Res.253 (WRC-23)
1.14		Res.254 (WRC-23)
1.15	7B	Res.680 (WRC-23)
1.16	7D	Res.681 (WRC-23)
1.17	7C	Res.682 (WRC-23)
1.18		Res.712 (WRC-23)
1.19		Res.674 (WRC-23)

Source: Elaborated by the authors.

It is important to emphasize that the security of aeronautical services is critical for the protection of people and property; therefore, measures must be taken to prevent excessive channel occupation and interference from other users, including 5G/6G networks (Eurocontrol 2022).

Since the WRC study cycle is still at the initial step of examining the items and preparing the SG, the steps to address interference issues, which may arise within the bands under consideration, are yet to be taken. Additionally, the SGs are still busy collecting information, which will ease them in interference reduction strategy analysis later. Thus, quantitative evaluations will only be feasible after the completion of extensive surveys on the technical aspects of the systems or items on the agenda item in question, the definition of the various interference scenarios that can be envisioned in the studies, and the specification of the formal numerical procedures to be applied for the interference calculations. The fulfillment of these steps will be decided only after a mutual agreement between the administrations and the key stakeholders in the negotiation of a particular item (WRC 2024).

In this context, this article aims to describe the WRC-27 agenda items that are of interest to civil aviation, mainly from the perspective of the ICAO, as well as to describe the analysis and opinions of different companies, institutional bodies, and administrations regarding these items. The article highlights the importance of regulatory agencies in identifying potential risks to aeronautical services and developing measures to mitigate them. Additionally, it explores the implications of spectrum limitations on aviation, particularly in the context of competing spectrum demands from other sectors, such as ICAO (5G and beyond) networks (3GPP 2025; Ahokangas and Asgaard 2024; ITU 2023). This study further provides a timely addition to current literature by conducting an inquiry into the most prominent aviation-spectrum management interface, in light of the forthcoming WRC-27. It makes several fundamental contributions, such as:

- Risk identification: the study recognizes some likely risks to aeronautical services owing to increased demand for spectrum, specifically by International Mobile Telecommunications (IMT) networks;
- Regulatory insight: on a perception analysis basis of the top stakeholders, comprising the ICAO and other regulators, the report offers a description of the regulatory scenario as it is;
- Actionable advice: the article recommends particular attention to the aeronautical system used for the safety of life by the regulatory bodies so that perils can be decreased toward these services;
- Research framework in the future: finally, through an identification of research gaps in studies concerning spectrum management and aviation, the paper forms the basis of research in the future.

The article is organized as follows: next section describes the relevance of the discussion on the WRC-27 agenda items of interest to civil aviation, with particular attention to agenda item 1.7; following, it is presented the challenges and opportunities for aeronautical radiocommunications, from the perspective of ICAO and other interested groups; next, the paper gives an example of a methodological approach to analyze compatibility between IMT and radionavigation services; finally, it is presented the final comments and future perspectives.

Relevance of the discussion on aeronautical items at WRC-27

The aviation industry constitutes a significant component of the global economy and serves as a fundamental foundation for the growth of connectivity, commerce, and tourism. Air travel, for example, accounts for around 4.1% of global Gross Domestic Product. Air transport is responsible for moving 8.3 trillion dollars in trade. Over the next 20 years, the number of passengers is expected to grow by an average of 3.8% per year, resulting in over 4 billion additional trips by 2043 compared to 2023 (ICAO 2024). In addition to the technical requirement, there is an economic aspect to ensure that airspace operations are safe and efficiently regulated, as the consequences of disruptions in this domain are critical. This assertion is further substantiated by the works of Babinski *et al.* (2024) and Fulindi *et al.* (2022), which highlight the multifaceted nature of airspace efficiency and safety, a concept that encompasses a wide range of disciplines. For these reasons, several studies deal with communication systems used in aircraft and related components, such as the global navigation satellite system (GNSS) (Brogi and Tromboni 2015; Marini-Pereira *et al.* 2021; Pessoa and Fraga 2024).

As mentioned in the previous section, the ITU-R SGs and their respective working parties provide the technical basis for decisions taken at the WRC, in addition to developing global standards (Recommendations), Reports, and Manuals on issues related to radiocommunication. Due to the importance of aeronautical services, the ITU maintains within SG-5, WP 5B, which is responsible for the aeronautical mobile service, radiodetermination service and maritime service (ITU 2024b; Zhang 2021).

When it comes to civil aviation, ICAO is the United Nations agency responsible for formulating the international regulatory framework. The Convention on International Civil Aviation is a treaty that establishes the provisions necessary to ensure the safety of flights over the territories of member states, as well as over international waters. The Standards and Recommended Practices (SARPs), designed to facilitate air navigation, constitute a legal framework, which covers personnel licensing, technical requirements for aeronautical operations, airworthiness requirements, specifications for aerodromes and systems used in the provision of radiocommunication, navigation, and surveillance services, in addition to other technical and operational requirements (ICAO 2024). ICAO is responsible for addressing spectrum issues on a global scale that are relevant to the aviation industry. Another key aspect of its role is the coordination of the sharing of frequency bands among civil and military applications (Molleryd *et al.* 2024).

With regard to radiocommunication services, the studies carried out by ICAO involve not only the adaptation of its systems to the communication devices and technologies currently in use in civil aviation, but also have a prospective vision that ensures harmonious integration with technological advances in the aeronautical sector not regulated by ICAO, as well as in systems that are not strictly aeronautical, which are also dealt with within the scope of the ITU (ICAO 2024).

In accordance with the proceedings of WRC-27, specifically within the framework of WP 5B, a proposal was made encompassing only two items for study: 1.8 and 1.9. However, this article will describe the items of relevance to civil aviation, based on the ICAO perspective, which include items: 1.5, 1.7, 1.9, 1.11, 1.12, 1.13, 1.15, 1.16, 1.17, 1.18, and 1.19, which may affect the use of spectrum by aviation; it is essential that the competent aeronautical bodies participate in the studies to ensure that there are no undue impacts (ICAO 2024; WRC 2024). Item 1.8 will not be described since ICAO considers it to have no impact. It is also important to highlight that ICAO's position must be aligned with the information presented in the (ICAO 2018), which outlines the long-term policy of the institution.

Challenges and opportunities in the harmonization of aeronautical radiocommunications

ICAO position for WRC-27

This section will address ICAO's position for items of interest in WRC-27, as described in Table 2. The primary objective of this section is to draw the attention of the academic community to the aeronautical-related agenda items that will be discussed at WRC-27, particularly those involving scenarios where interference may lead to catastrophic failures (ITU 2024a).

Viewpoint of other relevant groups

In this section, information relevant to items of interest to ICAO will be described, according to the view of other entities, for monitoring and possible future actions. Special attention will be given to agenda item 1.7 since it has been the most discussed during the various meetings in preparation for WRC-27, due to its possible impact on flight safety, as previously described.

Initially, Table 3 describes the position of the Space Frequency Coordination Group (SFCG), an international group whose goal is to ensure the efficient and safe use of the spectrum for space communications systems, such as satellites, while avoiding harmful interference between the systems of different countries and organizations (SFCG 2024).

Table 2. ICAO Position for WRC-27 (ICAO 2024).

Item	Item description	ICAO position	Debates/challenges
1.5	Unauthorized operation – Examine regulatory actions to prevent unauthorized operations of earth stations in non-geostationary-satellite orbits (NGSO) within the fixed-satellite and mobile-satellite services.	Ensure that the consequences of this item do not lead to new regulatory and technical restrictions for NGSO satellite systems, avoiding negative impacts on the Aeronautical Mobile Service En Route (AMS(R)S) and emergency frequencies used by aviation.	The scope includes aeronautical services in the frequency bands 117.975–137 MHz (voice and data for air traffic control [ATC]); 1,087.7-1,092.3 MHz (global flight tracking); 1,610-1,626.5 MHz (ATC voice and data); and 5,000-5,150 MHz (RPAS). Also, RR No. 5.200 has updated to include AMS(R)S for the aeronautical emergency frequency at 121.5 MHz. It is important to maintain the integrity and avoid operational restrictions of emergency and distress communication services. Issues: concerns from aviation and satellite industries over potential interference with critical services. Potential risk to aviation: low.

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Item	Item description	ICAO position	Debates/challenges
1.7	IMT 4.4, 7, 8 & 15 GHz – Study on IMT in the frequency bands 4,400 to 4,800 MHz, 7,125 to 8,400 MHz (or parts thereof) and 14.8 to 15.35 GHz, considering the primary services existing in these and adjacent bands.	Oppose any new IMT identification in the 4,400-4,800 MHz band that could reduce protection or impose additional constraints on radio altimeters and Wireless Avionics Intra-Communications (WAIC) in the 4,200-4,400 MHz band, and ensure that this agenda item do not compromise the protection or impose new constraints on aeronautical systems in the 15.4-15.7 GHz band.	The frequency band 4,200 to 4,400 MHz, adjacent to the 4,400 to 4,800 MHz range, is allocated to the Aeronautical Radionavigation Service (ARNS). It is reserved exclusively for radio altimeters installed on aircraft and for associated transponders on the ground (as per regulation 5.438). Additionally, the use of the 4,200 to 4,400 MHz frequency band by stations in the AM(R)S is exclusively reserved for WAIC. These systems must operate in compliance with recognized international aeronautical standards (as per RR 5.436). The frequency bands 7,250 to 7,750 MHz (downlink) and 7,900 to 8,400 MHz (uplink) are allocated on a primary basis to the fixed-satellite service (FSS) in many countries. For example, in Brazil, these bands are specifically allocated and assigned for the FSS exclusively for military and public safety applications; and the band 15.4 to 15.7 GHz is allocated on a primary basis to airborne weather radars, precision approach radars, airport surveillance detection equipment and detect and avoid radars, and other important X-Band Space Services (Allison 2024). According to RR 1.10, aeronautical radionavigation corresponds to "…radiodetermination used for the purposes of navigation, including obstruction warning". In practice, this function is basically performed by the radio altimeter, which according to RR 1.108 is the "…equipment, on board an aircraft or spacecraft, used to determine the height of the aircraft or the spacecraft above the Earth's surface or another surface" (ITU 2024a). According to ICAO, the radio altimeter is the avionics that provides accurate height measurements above the Earth's surface during the approach, landing, and ascent phases of the aircraft's operation. Issues: military and aviation sectors resist IMT allocations due to interference risks, since the demand for wireless broadband services and, consequently the spectrum for allocating these services continue to grow dramatically. 5G and beyond technologies seeks to provide higher data transmission speeds and connectivity for various applications (Ahokangas and Asgaard 2024; ITU 2023). Therefore, IMT may be a threat for aeronautical services. Potential risk to aviation: high.
1.9	Aero HF AM(OR)S, Appendix 26 – Consider regulatory actions to update RR, Appendix 26, to support the modernization of the aeronautical mobile (off-route) service (AM(OR)S) on high frequency (HF).	Ensure that the outcomes of this item do not undermine the protection or impose additional constraints on internationally aeronautical HF safety communications.	Changes to the waveform, bandwidth, or emissions in adjacent AM(OR)S allocations could impact in the AM(R)S frequency range. HF remains the only terrestrial service providing global communication coverage for aircraft – essential for safety and flight communication in remote areas. Access to the 2,850-22,000 kHz range is critical for aviation safety. Issues: prioritizing aviation over other HF new applications. Potential impact on traditional HF users like maritime and military sectors. Potential risk to aviation: low.
1.11	Space-to-space links in the GSO/NGSO L-band for Mobile-Satellite Service (MSS) – Examine the technical, operational, and regulatory aspects of space-to-space links between NGSO and GSO satellites in L-band.	Ensure that the outcomes of this item do not compromise the protection or impose additional regulatory or technical constraints on safety-related aeronautical satellite communications in the 1,545-1,555 MHz and 1,646.5-1,656.5 MHz bands, as well as in the 1,555-1,559 MHz, 1,656.5-1,660.5 MHz, and 1,610-1,626.5 MHz bands, and on aviation radionavigation satellite service receivers in the adjacent 1,559-1,610 MHz band.	Frequency bands 1,525-1,559 MHz and 1,626.5-1,660.5 MHz are allocated to the MSS and are used for aeronautical satellite communications (SATCOM), especially for ATC. Also, RR 5.357A provides priority to the AMS(R)S in bands 1,545-1,555 MHz and 1,646.5-1,656.5 MHz. Likewise, footnote 5.362A gives similar priority to AMS(R)S in the bands 1,555-1,559 MHz and 1,656.5-1,660.5 MHz in one administration. Band 1,610-1,626.5 MHz is allocated to AMS(R)S on primary basis, and is used for aviation SATCOM. Adjacent band 1,559-1,610 MHz is allocated on primary basis to the ARNS and RNSS, used by GNSS receivers. Issues: debate on safeguarding adjacent bands for aviation safety. Disagreement on whether mobile satellite service allocations should prioritize commercial or safety-critical applications. Potential risk to aviation: high.

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Item	Item description	ICAO position	Debates/challenges
1.12	Low data rate for MSS NGSO in L and S bands – Consider possible allocations for MSS and possible regulatory actions in L and S bands for future development of low data rate links.	Ensure that the outcomes of this item do not reduce protection or impose additional regulatory or technical constraints AMS(R) S in the 1,646.5-1,656.5 MHz band, where No. 5.357A applies.	The 1,435-1,535 MHz band is a priority for aeronautical mobile telemetry (AMT) in Region 2, and it is used for aircraft certification. The 1,626.5-1,660.5 MHz band is allocated to MSS, where 5.357A provides priority in the band 1,646.5-1,656.5 MHz to AMS(R)S. Furthermore, the band 1,626.5-1,660.5 MHz is used for SATCOM air-ground communications for ATC. The potential future use of the 1,645.5-1,646.5 MHz band by low data-rate NGSO MSS systems should take into account the need for co-existence with adjacent bands, ensuring that current and future aviation safety systems are not affected. Issue: differing perspectives on interference risks with existing aeronautical and GNSS systems. Lack of international consensus on power limits for new allocations. Potential risk to aviation: low.
1.13	MSS for direct connectivity between space stations and IMT – Analyze new allocations to the MSS for direct connectivity between space stations and IMT user equipment to complement terrestrial coverage.	Oppose any new allocations or regulatory actions that overlap the frequencies used by civil aviation in the 694 to 2,700 MHz band. Ensure that the studies related to adjacent bands for aeronautical systems do not reduce protection or impose additional regulatory or technical restrictions on civil aviation systems operating within this band. Additionally, these actions should not impact primary surveillance and weather radars operating adjacent the upper limit of this band.	ICAO has identified several systems essential for aviation safety that operate in the band 694 to 2,700 MHz or in adjacent bands: - 960-1,164 MHz: ACAS, ADS-B, DME, LDACS, MLAT, SSR radars and UAT; - 1,164-1,215 MHz: DME and GNSS; - 1,215-1,300 MHz: GNSS and primary surveillance radar (PSR); - 1,300-1,370 MHz: PSR for ATC; - 1,525-1,559 MHz: SATCOM. - 1,559-1,626.5 MHz: GNSS; -1,610-1,660.5 MHz: SATCOM; -1,626.5-1,660.5 MHz: SATCOM (RR 5,357A and RR 5,362A). - 2,700-2,900 MHz: PSR and weather radar. These systems should be considered in studies, as satellite transmissions to improve IMT coverage may affect the operation of aeronautical services. Issue: concerns over spectrum overlap with aviation and safety communication bands. Potential conflict interests between mobile operators and aviation safety authorities. Potential risk to aviation: high.
1.15	Lunar allocations – Consider studies on potential new allocations or modifications within the Space Research Service, for the future development of communications on the lunar surface and between lunar orbit and the lunar surface.	Ensure that studies protect systems supporting aeronautical services, particularly those operating in the 2,700-2,900 MHz, 3,600-4,200 MHz, and 5,350-5,470 MHz frequency bands. Also, ensure that proposed methods do not impose constraints on aviation systems essential for the safe operation of international civil aviation.	Several aeronautical systems are operating within the band or in adjacent bands to those considered in this item: - 2,700-2,900 MHz: Airport surveillance and meteorological ground-based radars; - 3,600-4200 MHz: ATC GSO satellite downlink and MSS feeder links; - 5,109-5,150 MHz: AeroMACs; - 5,150-5,250 MHz: AMS limited to AMT from aircraft stations in Brazil; - 5,350 -5,470 MHz: ARNS and used by airborne weather radar; - 5,600-5,650 MHz: meteorological ground-based and radiolocation radars. Issue: balance spectrum needs for Earth-based and space-based applications to ensure sustainable and efficient use of radio spectrum resources in the lunar environment (Schier et al. 2024; Sham et al. 2024). Potential risk to aviation: low.
1.16	Non-GSO Radio Quiet Zones (RQZs) – Exame protection of radio astronomy service (RAS) operating in specific RQZs and within the globally allocated bands to the RAS on a primary basis, from aggregate radio frequency interference caused by NGSO satellite systems.	Ensure that any measures related to this item concerning RQZs do not impose operational and development restrictions on NGSO satellite operating in the AMS(R)S and RNSS bands.	Aviation uses NGSO constellations for AMS(R)S and RNSS, with usage expected to increase in the coming years. Coordination between RAS and ATC can be established on a national level; and international coordination for ATC lead to additional delays and increased fuel consumption for aviation. Studies should be conducted to assess how the aggregate interference from unwanted emission of multiple NGSO satellites operating in bands adjacent to and near those listed in RR Resolution 681 (WRC-23) may impact the RAS. Issue: potential discussions between scientific research and commercial satellite deployment. Potential risk to aviation: low.

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Item	Item description	ICAO position	Debates/challenges
1.17	Allocations for space weather receivers – Regulatory provisions for receive-only space weather sensors and their protection.	Support regulatory changes for receiving space weather, ensuring that any changes do not impose technical or regulatory constraints on aeronautical systems.	Receiving space weather sensors are becoming increasingly important for detecting solar activity that can negatively impact aviation. Space weather contributes to sustainability of aviation and international civil aviation stakeholders should support the protection of space weather receivers. One of the issues identified is the lack of a unified approach to the frequency bands used globally. Issue: discussions about what bands should be prioritized for such sensors. Potential risk to aviation: low.
1.18	EESS (passive) & RAS above 76 GHz – To consider, based on studies, possible regulatory measures for protecting the Earth Exploration Satellite Service (EESS) and the RAS from unwanted emissions generated by active services.	Ensure that studies carried out foreign object debris (FOD) detection systems operating in the 92 – 94 GHz band. Ensure that any action taken in the 86 - 92 GHz bands do not impose technical or operational restrictions on FOD detection systems in that band.	Aviation operates several FOD radars systems in the 92-100 GHz band, which is close to one of the proposed EESS bands. Issue: spectrum sharing between active and passive services is a major challenge. Potential risk to aviation: low.
1.19	EESS (passive) SST at 4 and 8 GHz – Consider possible primary allocations in all Regions for the EESS (passive) in the bands 4,200-4,400 MHz and 8,400-8,500MHz.	Ensure that any changes do not impose technical, regulatory or operational restrictions on radio altimeters or WAIC systems in the 4,200 to 4,400 MHz frequency band, while recognizing the benefit that sea surface temperature measurements provide to civil aviation for weather forecasting.	The considerations for this item are like those for item 1.7, since it involves the operation of a radio altimeter, which is extremely important for flight safety. Issue: risk of interference with radio altimeters and aeronautical communications. Aviation strongly opposes these allocations due to safety concerns. Potential risk to aviation: low.

Source: Adapted from ICAO (2024).

Table 3. SFCG position (SFCG 2024).

Item	SFCG Position
1.11	Safeguards the 1 670-1 675 MHz band (MetSat) during the formulation of regulatory provisions for the operation of space-to-space links.
1.12	It does not oppose possible new allocations for MSS for low data rate NGSO systems, provided that following conditions are guaranteed: the protection of the EESS (1,400-1,427 MHz), through mandatory limits on unwanted emissions; and absence of negative impacts on the EESS, SOS, and SRS systems (2,025-2,110 MHz).
1.13	Supports new allocations to MSS only for supplemental IMT ground coverage in the bands identified for this purpose. It does not oppose to new MSS allocations for direct connectivity between space stations and IMT equipment, provided that the following conditions are guaranteed: protection of the EESS (1,400-1,427 MHz); no negative impact on the MetSat (1,675-1,710 MHz); no negative impact on EESS/SOS/SRS (2,025-2,110 MHz and 2,200-2,290 MHz); no negative impact on SRS (2,110-2,120 and 2,290-2,300 MHz).
1.15	Supports new or modified SRS allocations for development of lunar communications and the protection of the Safety Zone of the Moon for RAS.
1.17	Supports primary frequency allocations for MetAids (space weather) receive-only sensors, without placing any restrictions on existing services in these bands.
1.18	Endorses mandatory limits on unwanted emissions from active services to protect EESS operations in specific frequency bands (86-92 GHz, 114.25-116 GHz, 164-167 GHz, and 200-209 GHz).
1.19	Endorses primary EESS allocations in the 4,200-4,400 MHz and 8,400-8,500 MHz bands to maintain sea surface temperature monitoring capabilities, preserving existing services.

Source: Adapted from SFCG (2024).

The Electronic Communications Committee (ECC) of CEPT will monitor the development of item 1.7, especially regarding the criticality of 4,400 to 4,800 MHz for aeronautical and maritime mobile applications. It is worth noting that this band has already been analyzed at WRC-15 and CEPT was unfavorable to the allocation of IMT (CEPT 2024b; ECC 2024). The most recent CEPT/CPG (Conference Preparatory Group) meeting took place in December 2024, but the final documents were not available until the closing of this article (CEPT 2024a). During this meeting, RCC also presented its preliminary position on the items (RCC 2024). In relation to item 1.7, they believe that the protection of frequency assignments for Aeronautical Mobile Service (AMS) and Membership Management Software (MMS) stations in international airspace and waters can only be guaranteed with the consent of the affected administration(s) through bilateral or a multilateral coordination. Also, at the last CEPT meeting, the APT presented its preparation activities for WRC-27, but did not describe its position on the agenda items.

ATU held its first preparatory meeting for WRC-27 between July and August 2024. On that occasion, working groups were defined with the aim of coordinating proposals, strategies, and action plans that can be useful to African countries. A strategic plan was also discussed to ensure that the continent's interests are effectively represented during the conference (News Desk 2024).

Members of the WMO, through their National Meteorological and Hydrological Services (NMHS) and related agencies, provide a wide range of essential services for the observation of meteorological, water, climate, and related environmental events, which is why the Table 4 describes the position of this organization (WMO 2024).

Table 4. WMO position.

Item	WMO position
1.7	Expresses concern on this issue, since the introduction of IMT networks could limit the future development of MetSat and EESS stations, which are vital for the distribution of meteorological and environmental data to the WMO user community. Furthermore, WMO requests that the impact of IMT operations in the 4,400-4,800 MHz and 8,215-8,400 MHz bands be considered in relation to new EESS allocations.
1.11	Not oppose studies for space-to-space links between GSO and NGSO satellites in bands allocated to the MSS, if there is no negative impact on the environment for MetSat systems in the 1,675-1,710 MHz frequency band.
1.12	Not oppose the consideration of MSS allocations for low data rate applications, provided that studies are conducted for the protection of EESS in the 1,400-1,427 MHz band, these studies define limits for unwanted emissions, and there is no negative impact for EESS/SOS in the 2,025-2,110 MHz frequency band.
1.13	No opposition to new allocations for the MSS that allow connectivity between space stations and IMT user equipment provided there are no negative impacts on adjacent bands related to MetSat (1,675-1,710 MHz), EESS/SOS (2,025-2,210 MHz), and weather radar systems (2,700-2,900 MHz).
1.17	Supports new primary allocations for MetAids (space weather) for receiving sensors in all frequency bands listed in the item.
1.18	Supports the development of mandatory regulatory provisions for active services to ensure the long-term protection and usability of the EESS frequency bands, including 86-92 GHz, 114.25-116 GHz, 164-167 GHz, and 200-209 GHz.
1.19	Supports new primary EESS allocations in the 4,200-4,400 MHz and 8,400-8,500 MHz frequency bands.

Source: Adapted from WMO (2024).

CITEL will monitor the progress of the WRC-27 agenda items, but so far only preliminary views (PV) have been presented, which, during the study cycle, could become an inter-American position for WRC-27 (CITEL 2024).

Global System for Mobile Communications Association (GSMA), an organization that brings together more than 1,000 mobile operators and related companies and sectors worldwide, considers that the bands proposed in item 1.7 could be designated with the aim of providing capacity for the future of mobile systems. The association highlights that in the 2030s, a new era of connectivity will require some specific spectrum requirements and these bands represent a potential resource for the next phase of mobile evolution. In addition, there is interest in enabling technologies related to the direct-to-device system, which allows direct connectivity between satellites and standard smartphones, without the need for additional equipment (GSMA 2024a).

According to the European Space Policy Institute (ESPI 2024), WRC-27 is expected to consider several new frequency allocations and regulatory actions that will benefit the space sector, including but not limited to the future development of low-data-rate NGSO mobile satellite systems. Furthermore, it is noted that the study related to item 1.7 covers a portion of the Ku-band, which is widely used by satellites, and the 7 GHz band, adjacent to the newly designated 6 GHz band, which may generate further debate within the Wi-Fi community.

5G Americas Group (Airspan Networks, Antel, AT&T, Ciena, Cisco, Crown Castle, Ericsson, Liberty Latin America, Mavenir, Nokia, Qualcomm Incorporated, Rogers Communications, Samsung, T-Mobile USA, Inc., and Telefónica) considers the 7,125-8,400 MHz band to be essential for the success of 6G in the Americas, due to its ability to cover large areas with mobile broadband. This is the only band that the U.S. and Canada agree on in item 1.7, and global harmonization of this band is crucial to take advantage of economies of scale, helping to reduce costs and, consequently, improving the accessibility of IMT (5G Americas Group 2024). Furthermore, a common and globally harmonized spectrum band is essential for the development of telecommunications, since spectrum fragmentation creates difficulties for global roaming and increases costs for equipment manufacturers, network operators and consumers. Therefore, 5G Americas Group considers it imperative that administrations make efforts to allocate this band for IMT, even if this requires spectrum sharing mechanisms between existing services and commercial mobile users (5G Americas Group 2024).

It is worth noting that the bands proposed in item 1.7 for IMT (6G technology) represent a critical geopolitical issue, since these bands overlap with essential frequencies used by the armed forces of the North Atlantic Treaty Organization (OTAN). Several countries use the 4,400-4,800 MHz band for fixed, mobile, and aviation applications, the 7,250-8,400 MHz band for satellite connectivity, and the 14.8-15.3 GHz band for wireless systems, including those intended for drones and remotely piloted aircraft systems (RPAS) (Bubley 2024). Furthermore, it is necessary to highlight the importance of managing the spectrum of frequencies used by RPAS, given the complexity of both its operational scenarios and its communication systems. In fact, their operation relies heavily on robust, adaptive communication networks capable of providing safety and reliability, especially in dynamic and congested environments. Works such as Borodin *et al.* (2024a; b) and Chechin *et al.* (2023) provide insight into the main challenges and strategies for organizing communication channels, optimizing routing metrics, and providing reliable network performance. Therefore, it is extremely important that bands considered under item 1.7 are not designated for exclusive and high-power use, and that they do not interfere with the security services in operation (Bubley 2024). Additional discussions about agenda item 1.7 can be found in 5G Americas Group (2021), Li *et al.* (2024), and RTCA (2020).

As previously analyzed, there is an urgent need to explore methods for spectrum sharing and compatibility, as well as to establish the necessary conditions for the effective implementation of innovative technologies within frequency bands, including those adjacent to those allocated to aeronautical services. This need is highlighted by the potential risks to civil aviation, emphasizing the critical importance of protecting aeronautical systems, particularly those directly related to flight safety. Ensuring the protection of these systems is crucial not only to maintain operational integrity but also to prevent potential disruptions that could affect air traffic management and overall aviation security.

Methodological approach to analyze compatibility between IMT and radionavigation services

Methodology for the technical study

Over the past few years, several studies have been carried out with the aim of analyzing the interference of 5G base stations with aeronautical systems, based on advanced computer models, various flight scenarios and conditions, and different configurations of mobile networks (Amaireh and Zhang 2024; Zhang *et al.* 2024). Another way to evaluate IMT interference is based on real-world tests. On the other hand, it is important to consider that directly measuring the combined interference in real-world tests before network deployment is almost impossible. These tests typically involve only a small number of devices, far too few to create any meaningful interference for the receivers being tested. As a result, computer simulations become the only viable method for estimating the total interference from cellular systems operating across large areas (Pastukh and Sorokin 2023).

Based on ICAO (2023) and ITU-R (2014a), a methodology for assessing potential IMT interference with aeronautical systems, aimed at defining safeguarding measures to protect flight operations, could be outlined as follows:

- Identify the frequency band and area of interest;
- Identify the location of the base station or IMT mobile network;
- The primary evaluation should be on one 5G base station to establish its potential threat to aviation equipment or systems;

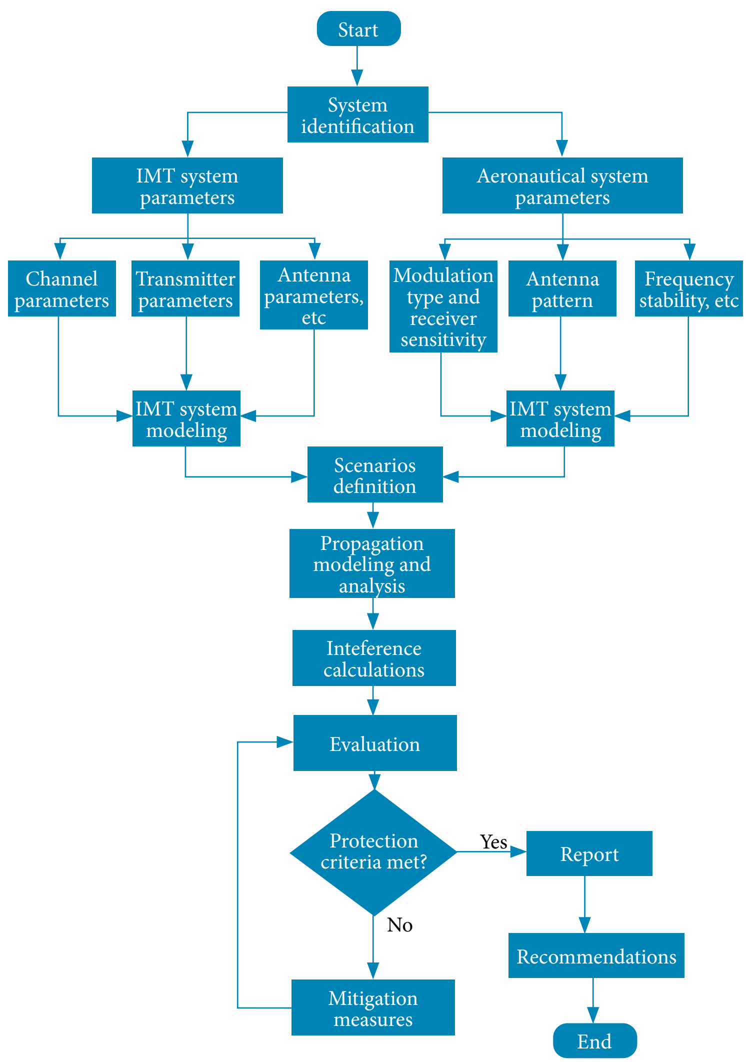
Identify list of parameters:

• 5G base station parameters: true radiated power (TRP), antenna gain – active antenna systems (AAS), adaptive beamforming; or non-AAS antennas – fixed beam; maximum effective isotropic radiated power (EIRP); base station site and antenna tilt, etc.
• Aeronautical system parameters: transmitted power, receiver sensitivity, including filtering characteristics and installations, etc.
• System modeling (mathematical or computational modeling).

Identify operational and environmental factors:

• Generalize the baseline scenario and investigate the impact on all aeronautical systems. Recommendation ITU-R M.2059 (ITU 2014a) gives an example for the radio altimeter scenario.
• Based on the parameters raised, evaluate the possible impacts of IMT networks on the aeronautical system and consider possible mitigation solutions.

Figure 2 illustrates the process for interference analysis, which guarantees a thorough assessment of the IMT interference potential risks to aeronautical systems. Additional details on the methodology described, including practical examples and mathematical development can be found in Dridi (2023) and ICAO (2021).



Source: Adapted from ICAO (2023) and ITU-R (2014a,b).

Figure 2. Process for interference analysis.

It is important to note that, until now, no formal methodology has been defined for calculating/simulating IMT interference in aeronautical systems, given that the ITU-R SG is still carrying out the initial phase of analysis and data collection.

As shown in Fig. 2, a crucial decision point in the sharing and compatibility, analysis process is the definition of the protection criteria of the system against interference.

The protection criteria for radio systems in aeronautical services, as defined by the ITU-R, play a fundamental role in ensuring the integrity and operational safety of aeronautical communication and radionavigation systems. Given the critical nature of these systems – where even minor interference may compromise flight safety – strict adherence to these criteria is essential. They establish the necessary technical parameters to minimize harmful interference, including precise frequency allocations, interference thresholds, and mitigation strategies to prevent disruptions from external radio frequency sources (ITU-R 2024a).

As illustrated in Fig. 2, when the protection criterion is not satisfied, the adoption of measures to mitigate identified interferences becomes imperative. In this context, Table 5 presents a comprehensive set of potential mitigation measures for interferences caused by IMT systems in aeronautical radiocommunication systems. These measures are meticulously evaluated considering both the expected outcomes and their impact on aeronautical systems.

Table 5. Possible mitigation procedures and respective impacts.

Mitigation procedure	Expected results	Positive impacts	Negative impacts
Improvement of the radio project	Increased immunity to interference	Increased operational safety in aviation and reduced risk of instrument takeoff and landing failures	High cost of developing and replacing existing equipment
Use of filters in 5G/6G transmitters	Reduced interference in adjacent lanes	Better coexistence between 5G/6G networks and aeronautical systems	Need to upgrade telecommunications infrastructure and impact on 5G/6G coverage
Beamforming and directional antennas	Lower signal radiation in flight corridors	Reducing interference without compromising the efficiency of 5G networks	Continuous adjustments to antenna configuration and impact on mobile network performance
Digital signal processing	Efficient detection and suppression of interference	Improved robustness of avionics systems	High computational complexity and need for greater processing power in equipment
Guard bands and spectral separation	Reduced risk of overlapping frequencies between 5G networks and aeronautical systems	Effective protection against interference without the need for significant modifications to the systems	Reduction of spectral efficiency and restriction in frequency allocation for telecommunications
Power restrictions and antenna targeting	Minimizing the impact of interference in critical areas	Increased predictability and control of interference in sensitive areas	Potential impact on 5G service quality in certain regions
Equipment certification and testing	Ensuring compatibility between 5G networks and aeronautical systems	Increased system reliability and global standardization	Regulatory processes can be time-consuming and costly for manufacturers
International standardization	Harmonization of standards between telecommunications and aviation	Improved global coordination and reduction of regulatory conflicts	Challenges in simultaneous implementation in different countries and resistance from stakeholders
Exclusion and buffer zones at airports	Reduced interference in critical takeoff and landing areas	Immediate protection of aeronautical systems from harmful interference	Impact on 5G coverage in airport areas and possible trade restrictions
Continuous monitoring and interference detection	Real-time identification of potential interferences	Rapid action to mitigate operational risks	Need for investment in monitoring and data analysis infrastructure
Aeronautical procedures update	Better preparation of pilots and controllers to deal with interference	Reduction of operational risk in the event of failure of radio altimeters	Need for frequent training and adaptation of regulations
Recommendations for passengers	Minimizing the risk of interference caused by mobile devices	Passenger awareness and collaboration in flight safety	Difficulty in monitoring and dependence on voluntary compliance with recommendations

Source: Adapted from ITU-R (2014a; 2024b).

Finally, once the protection criteria are satisfied, it is essential to document the conditions and scenarios considered. This documentation serves as a foundation for developing recommendations or regulations aimed at safeguarding aeronautical services in future implementations.

FINAL COMMENTS

This paper began with the presentation of aviation-specific WRC-27 agenda items by various stakeholders. The focus subsequently shifted in the literature review to be more analytical. This research now examines the intricate interrelationship between aviation, spectrum management, and the WRC-27 agenda. By doing so, it is easier to discern relevant debates and compelling challenges for aviation and some possible solutions suggested by researchers as well as practitioners. This study adds value by: 1) mapping the literature om spectrum management's effects on aviation, specifically to the WRC-27 agenda, as a foundation for subsequent research; 2) balancing stakeholder stances; and 3) providing an overview of issues and opportunities for aeronautical radiocommunications from the perspective of WRC-27, facilitating policy consideration and regulation-making.

The management of the radio frequency spectrum involves establishing a legal framework to ensure the efficient use of this scarce resource while addressing of the various radio services. Globally, the ITU tackles this issue by establishing specific regulations, guiding national telecommunications authorities in implementing these standards, and recognizing the importance of radiocommunications in critical applications such as civil aviation. In this context, the ITU plans to review these resolutions during the WRCs with the goal of monitoring scientific and technological developments and emerging applications in this field.

The preparatory studies for WRC-27 cover a range of relevant topics to civil aviation. This paper provides a comprehensive analysis of these topics, while also considering the views of ICAO and other relevant organizations regarding potential impacts on existing aeronautical services. According to ICAO, the compatibility and harmonization of the radio frequency spectrum not only enhance the efficiency of technological solutions that benefit aviation more broadly.

As the preparatory stages for WRC-27 progress, it is important to reflect on the significance of spectrum sharing. This approach enables multiple services to coexist within the same frequency band, promoting technological evolution and global availability. Spectrum sharing can bring a range of benefits, including driving innovation in communication systems and power supply to support these technologies. It also enhances the availability and reliability of services for end users. However, implementing this concept requires careful planning, which leads to higher costs. Therefore, it is essential to explore ways to implement this concept that benefit administrations, promoting efficient spectrum use and encouraging international collaboration amidst rapid technological evolution. Additionally, it is important to highlight that technical and regulatory measures alone are insufficient to address the growing demands for frequency bands. National contexts and economic strategies, such as administrative pricing and frequency band auctions, must also be considered.

In this sense, the main objective of this paper is to highlight the aeronautical-related agenda items set to be discussed at WRC-27, with a particular focus on scenarios where interference could result in catastrophic failures. More specifically, it seeks to engage the scientific community in conducting comprehensive studies on the compatibility and sharing between aeronautical services and potential interfering systems. Such studies are essential for quantitatively assessing the potential impacts of IMT and, ultimately, for establishing protection criteria and interference mitigation measures to safeguard aeronautical systems.

It is also worth noting that in November 2024, another WP 5B meeting was held, during which, among other topics, the liaison statements to be sent to other SGs were discussed. These statements include information on existing aeronautical systems, with the aim of protecting them from interference and ensuring the security of aeronautical communications. Furthermore, civil aviation must invest more in technological innovation, while regulatory agencies need to support the sector by improving spectrum utilization and preventing operational issues. The increasing demand for frequency bands will require commitments and collaboration from all stakeholders involved.

Finally, it is crucial that the national administration, through ANATEL, and the members of the Radiocommunications Reporting Group related to AMS, increasingly recognize the importance of the WRC. This will enable Brazil to proactively safeguard its position and sovereign interests, ensuring that the spectrum is not controlled by a few actors.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS' CONTRIBUTION

Conceptualization: Leite VCMN, Yaghdjian VA, and Silva Junior CE; **Investigation**: Leite VCMN, Yaghdjian VA, Silva Junior CE, Alves Filho LP, and Gebrim RC; **Methodology**: Leite VCMN, Yaghdjian VA, Silva Junior CE, and Alves Filho LP; **Writing – Original Draft Preparation**: Leite VCMN, Yaghdjian VA, Silva Junior CE, Alves Filho LP, and Gebrim RC; **Writing – Review & Editing**: Leite VCMN, Yaghdjian VA, Silva Junior CE, Alves Filho LP, and Gebrim RC; **Final approval:** Leite VCMN.

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