National Regulation of Satellite Ground Stations: A Global Comparison

Tommi Rasila and Arto Ojala

1 Introduction

Satellites and space activities are extensively regulated on both international and national levels, and this is well justified (Spencer, 2010). Satellites operate beyond national boundaries, potentially impacting any location on the planet when issues arise. In contrast, satellite ground stations have encountered comparatively limited regulation. Unlike space objects, they necessitate less international coordination as ground stations remain stationary, primarily affecting radio traffic within neighboring countries.

Nevertheless, satellite ground stations hold a crucial role within the space ecosystem (Elbert, 2008; Prol et al., 2022). Without them the satellites and all the data gathered with their state-of-the art sensors and

T. Rasila (✉)
NorthBase Oy, Tampere, Finland
e-mail: tommi.rasila@northbase.fi

A. Ojala
School of Marketing and Communication, University of Vaasa, Vaasa, Finland

Graduate School of Management, Kyoto University, Kyoto, Japan

A. Ojala
e-mail: arto.ojala@uwasa.fi

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cameras would be unusable. Satellites rely on commands from the ground to maintain their orbital positions and carry out their intended functions. Moreover, the data they gather often requires transmission back to the Earth's surface for processing and application. Consequently, satellite owners and operators require access to one, or ideally multiple, strategically located ground stations worldwide, tailored to accommodate the satellite's orbit and specific characteristics (see, e.g., Schmidt, 2011).

Although many countries have regulations associated with ground stations, either directly or indirectly, only a handful have specific laws dedicated to governing their ownership and operation. Conversely, several countries lack any distinct regulations, with global regulations primarily targeting satellites, consequently exerting an indirect influence on ground stations resulting in an uneven regulatory landscape, posing challenges for competition and offering opportunities to exploit regulatory gaps.

Based on the aforementioned facts, this study primarily focuses on examining the legal framework and regulations governing satellite ground stations. Our objective is to assess and analyze the regulatory landscape surrounding satellite ground stations across various countries worldwide. Consequently, the study aims address the following questions:

1. What types of regulations govern ground station operations globally?
2. How do ground station regulations enable ground station providers to operate in different countries?
3. Is there a necessity for international regulation or harmonization of regulations?

The data collection for this study was conducted using an open-ended qualitative email questionnaire (Dahlin, 2021) with local professionals from 16 countries, supplemented by a desk study of four additional countries. Using empirical data, we present a comparative analysis of regulations across nations, enriching our understanding of global ground station regulation. Moreover, we contribute current thinking by offering insights and recommendations for the potential development of both national and international regulations.

2 Literature Review

In this section, we will give an overview of ground stations and their importance in a space ecosystem. Thereafter, we will discuss the regulation of space activities in general and specific challenges related to the ground station regulations.

2.1 Ground Station as a Technical Device and Part of the Satellite System

The role of ground stations is crucial in both launching and operating satellites as they serve as the primary means of communication between Earth and satellites in orbit. A satellite mission typically spans several years, commencing with the design of the satellite and its payload, which often includes, e.g., cameras or measurement instruments (see, e.g., Gurtuna, 2013). Transporting the satellite into orbit necessitates a launch vehicle, typically a rocket, and a launch pad for lift-off. However, without reliable communication, these efforts would be futile. Communication through ground stations plays an essential role in two critical phases: first, in the launch and early orbit phase (LEOP), and then throughout the entire operational period until the mission concludes (Elbert, 2008).

The needs for ground stations vary significantly based on the purpose and orbit of satellites (Prol et al., 2022; Vasisht & Chandra, 2020). Geostationary (GEO) satellites are often considered relatively straightforward: due to their high orbit, they maintain a fixed position relative to the Earth, potentially covering nearly half of the globe. Therefore, they excel in applications such as broadcasting and communications, given their ability to relay large volumes of information across continents. Establishing a ground station for GEO satellites involves assembling an appropriately sized dish near the data source or destination, pointed toward the satellite's position (Elbert, 2008).

Satellites positioned in geosynchronous orbits (GSOs) or lower orbits, like medium-earth orbit (MEO) or low-earth orbits (LEO), present more challenges due to their constant movement relative to the Earth while in orbit (Prol et al., 2022). Also, the number and proportion of LEO is rising constantly (see, e.g., UNOOSA, 2024a).[1] As an example, the

[1] Additionally, numerous other satellites and space objects require ground communications. However, this study focuses on LEO, MEO, and GEO satellites, which collectively

GPS positioning system relies on MEO satellites, whereas satellite internet utilizes extensive LEO constellations, allowing the nearest visible satellite to provide connectivity to users within its range (Vasisht & Chandra, 2020). As the orbit altitude decreases, the visibility area on the Earth reduces. For instance, a typical LEO satellite orbits at heights between 400 and 1200 km with an orbital period of 90–128 minutes, resulting in a brief visibility window of around 20 minutes or less as it passes over observation points, such as internet clients or ground stations. Clients of these satellites use various types of antennas, such as small fixed antennas, array antennas, or tracking antennas (Fig. 1). For sending commands to the satellite or downloading greater amounts of data, ground stations with tracking systems and hi-directivity radio frequency (RF) antennas or optical links are needed.

Fig. 1 Two distinct types of tracking ground stations

represent most commercial and scientific space objects. As of early 2021, there were 4550 satellites in orbit, with 3790 in LEO, 139 in MEO, and 565 in GEO or GSO (Rome, 2023).

Fig. 1 Two distinct types of tracking ground stations: a VHF/UHF band ground station equipped with yagi antennas (left) and an S/X band station featuring a 3.9-meter paraboloid antenna housed within a weather-protecting radome (© Tommi Rasila, Northbase Oy)

The nature of the orbit impacts not only the number of ground stations required to communicate with a satellite but also their optimal locations (Fuchs & Moll, 2015; Vasisht & Chandra, 2020). Satellites on equatorial orbits necessitate ground stations near the equator, whereas polar orbit satellites benefit from locations near the poles. Moreover, a satellite in a sun-synchronous orbit (SSO) orbits the Earth in sync with the sun, resulting in a different path over the Earth during each 24-hour cycle. In practice, this means that to establish communication with an SSO satellite during each orbit, its operator needs ground stations positioned very close to the North or South Pole. Alternatively, they may require several stations at lower latitudes to sufficiently cover the satellite's path across the globe.

Ground station optimization raises the issue of international cooperation, a common practice in space research and particularly prevalent in the emerging new space economy. In space missions dating back to the 1960s, multiple ground stations were necessary worldwide to maintain constant communication with spacecraft. Likewise, in the new space economy, satellite operators require timely access to their satellites for various purposes: during the LEOP phase, the ability to issue commands for orbital corrections is crucial to prevent loss during the early stages. For remote sensing satellites, frequent, low-latency downloads enable rapid response times, fresher images, and increased download capacity (Prol et al., 2022).

This study will specifically focus on ground stations designed for LEO satellites on sun-synchronous polar orbits, considering that the majority of new satellites fall within this category. Moreover, the evident need for versatile global coverage by ground stations becomes particularly evident within this context. To meet the frequent communication needs of LEO satellite operators, ground station service providers must offer stations across numerous global locations to ensure the necessary low-latency access (Prol et al., 2022; Schmidt, 2011; Vasisht & Chandra, 2020). In theory, a ground station positioned at either the North or South Pole would provide optimal coverage, allowing visibility of the LEO satellite during each orbit. However, practical challenges, including access to electricity, internet connectivity, and maintenance services, render both options unfeasible. Even within the Arctic Circle, suitable ground station locations are limited, further compounded within the Antarctic Circle. Therefore, it becomes evident that diverse locations across various countries are essential for the successful operation of ground station services. However, the regulations for ground stations might vary significantly across countries, which is the topic we will focus on next.

2.2 Regulation of Ground Stations and Space Activities in General

A satellite operator can choose to establish their network of ground stations or utilize services from a ground station service provider (Tubío-Pardavila & Kurahara, 2021). In both scenarios, the network is presumed to cover multiple countries. Consequently, it is important to consider the regulations of all these countries in addition to those of the operator's home country.

There are various regulations governing space objects and ground stations (Spencer, 2010; Vasisht & Chandra, 2020) such as ground station and radio permits, licenses for transferring satellite data, and building permits. The regulations about space objects, like satellites, are more internationally harmonized, given that these objects transcend national boundaries and traverse nearly all countries globally. Consequently, it is crucial to regulate and coordinate aspects such as their uplink and downlink radio frequencies, power levels, orbital characteristics, and to mitigate risks associated with planned or unplanned re-entry into the Earth's atmosphere (see, e.g., Kurahara, 2018).

Despite its importance, there is minimal international coordination among ground stations, resulting in having each nation with its own set of regulations (see UNOOSA, 2024b). These regulations often comprise sporadic collections of laws and guidelines. This lack of uniformity could be attributed to the organic growth of the ground station industry. Similar to many emerging businesses, ground station establishment has occurred somewhat haphazardly across countries, conforming to existing regulations, primarily focused on aspects like radio frequency usage, export restrictions, and civil work regulations, including building permits.

Only recently have certain nations established specific ground station laws, in part to address both past and anticipated issues arising from an unregulated environment. These issues include instances of foreign entities, and even nation-states, constructing and deploying ground stations in countries where their satellite operations might be viewed as potentially hostile. Simultaneously, satellite operators and ground station service providers must navigate vastly differing regulatory landscapes across various countries. This dynamic renders some countries appealing for operations while making others practically impossible to operate within.

3 Research Method

Data for this study was collected by using an open-ended qualitative email questionnaire (Appendix 1). Even though face-to-face interviews would have helped to collect more detailed data, the email approach was selected due to excessive resources needed for traveling and difficulties finding common times for interviews as the interviewees were located around the world. Despite some weaknesses, email interviews can generate more in-depth and lengthier responses (Dahlin, 2021) than face-to-face interviews as respondents have more time to think about how and what to answer. Based on the first author's knowledge of the field, we approached 18 ground station experts in 18 different countries. These experts ranged from founders of a ground station company to people working in a notable position related to ground station activities. Altogether we received answers from 16 experts (see Table 1). Appendix 2 provides a list of participants and their organizations if they chose to provide that information.

A desk study was conducted on four countries—France, Germany, Norway, and Spain—to complement the email interviews covering 16 countries. This increased the total number of countries covered to 20. The literature and other sources used for the desk study are listed in Appendix 3. The validity and relevance of this sample are considered adequate for this study, given the spread of the research objects based on their geographical location, geopolitical position, and the developmental stage of the national space sector.

4 Findings

4.1 *Categorization of the Regulations*

Based on the empirical findings, the level and intensity of regulation vary greatly. In many countries, regulations are stringent, necessitating ground station operators to adhere to a set of implicit rules regarding

Table 1 Summary of the participants

Interviewee	*Country*	*Expertise*
A	Finland	Executive of a ground station service provider
B	Bulgaria	Executive of a ground station service provider
C	China	Freelance consultant
D	Italy	Executive of a ground station service provider
E	Sweden	Executive of a teleport services provider
F	Tanzania	Executive of a private space company
G	India	Executive of a small sat development company
H	UK	Executive of a ground station service provider
I	Republic of Korea	Executive of a ground station service provider
J	Ukraine	Executive of a ground station service provider
K	USA	Executive of a ground station service provider
L	Czech Republic	Executive of a ground station development company
M	South Africa	Executive of an EO specialist company
N	Japan	Executive of a ground station service provider
O	Kazakhstan	Official in a space research institution
P	Canada	Official in the regulatory body

ownership, technical standards, and security—both physical and cyber—as well as practices such as customer identification for security and geopolitical reasons, among others. These regulations naturally require a certain level of transparency and reporting. Based on this, regulators may impose requirements for logging activities and reporting to the regulatory body.

There are several types of regulations that are implied in ground station operations. Based on the collected data, three categorize emerged from the data:

1. *Specific* regulations, such as ground station laws and RF licensing.
2. *General* regulations, including building permits and export licensing.
3. *Hidden* regulations, such as those related to geopolitics and national security matters.

Only a few countries—such as the USA, and Finland—have *specific* laws pertaining to ground stations. In some countries—such as Canada, France, and Germany—ground operations are specifically addressed within legislation on space operations. In most countries, regulations primarily focus on radio operations. Transmitting from a ground station (transmit (TX), uplink) requires radio permission in all countries, and in some countries, receiving (receive (RX), downlink) also necessitates a license. A notable exception is Norway, which has different rules for mainland Norway compared to Svalbard and Antarctica due to treaties such as the Svalbard Treaty and the Antarctic Treaty. These treaties impose additional restrictions, such as limitations on military use of downloaded data.

In addition to ground station and radio permits, it is natural that *general* national permits required for building structures and operating businesses are also implied. While this group is not the focal point of this study, it should be noted that, broadly, the general permit processes for ground stations appear to be fairly lax. For example, ground stations are largely regarded as technical structures and thus usually do not require a building permit but rather just a notification. While physical security and occupational health issues are naturally observed, a more intriguing set of requirements is formed by cyber or information security, dual-use products, and export permits.

In many countries, specific requirements are set regarding cybersecurity, encryption, and the distribution of data. This is because remote sensing data, such as aerial photographs, can be utilized for malicious purposes. Consequently, there are also requirements to address dual-use and export regulations. Interestingly, while most countries have explicit rules and procedures for this, in some others, satellite data is not considered a dual-use product, and therefore export regulations are not applicable. Nevertheless, the acquired data is generally considered to have the potential to be of a critical nature.

When considering security matters further, the third group of regulations—the *hidden* ones—may come into play. These encompass implicit secondary rules embedded within the regulatory framework, such as policies that allow the regulator or state to make exceptions to the rules based on national security considerations. Additionally, other ministries besides the official regulatory bodies may become involved in regulatory decisions or changes. Situations may evolve with the formation or alteration of global alliances or shifts in international geopolitical conditions. These rules are often not transparently expressed, and their implementation may involve a certain level of secrecy.

This brings us to the nature of the regulating body, which varies greatly. To illustrate this diversity, a few examples are provided in Table 2.

Table 2 Examples of regulating bodies

Country	*Regulating body*
Canada	Global Affairs Canada (Non-Proliferation and Disarmament unit under foreign ministry) for remote sensing space systems and Innovation, Science and Economic Development Canada (federal dept) for ground stations and spectrum management
Finland	Traficom (licensing body of M.o. Transport and Communications) for ground stations and spectrum management and M.o. Economic Affairs and Employment for space objects
France	SGDSN—General Secretariat for Defence and National Security
Germany	BAFA—Federal Office of Economic Affairs and Export Control under Federal Ministry of Economic Affairs and Climate Action (formerly Economic Affairs and Energy)
India	IN-SPACe—Indian National Space Promotion and Authorization Center
USA	FCC, NOAA/DoC—The Federal Telecommunications Authority, along with the weather and ocean research organization within the Department of Commerce

This may result from the same development noted earlier regarding the differing collections of laws and regulations: When the need to regulate space issues first arises, there is no natural place for it. Space may be perceived as an issue of communications, traffic, aviation, science, international affairs, or security. As space becomes more integrated into everyday activities, it is often still regulated by the public body to which it was originally assigned. For example, in Sweden, satellites may fall under the jurisdiction of the Ministry of Education and Research, while ground stations may be overseen by the Post and Telecom Authority. Similarly, in France, space regulation may be managed by the General Secretariat for Defence and National Security.

To add complexity, regulatory bodies may differ for ground stations, frequency permits, and satellites. Additionally, the regulating body may be required to consult other ministries or state departments, and there may be multiple processes and permits that the applicant must navigate. As a result, the licensing process for a ground station can be quite intricate. Due to this complexity, in most countries, the number of applications is presumably very low, leading to potentially high administrative costs and burdens. However, there are also examples of streamlined processes, such as India's establishment of IN-SPACe as a one-stop shop for space permissions. Furthermore, some countries, including the UK, Ukraine, and Spain, only require a TX radio license, sometimes supplemented by notifying the regulatory body about the commencement of ground station operations.

4.1.1 Specific Laws and Regulations for Ground Stations

Less than half of the target countries have specific ground station regulations. For instance, Finland introduced a law on "ground stations and certain kinds of radars" on February 1, 2023, despite the practical non-existence of ground stations as a business. However, the law is forward-looking, as its title suggests: it anticipates future developments beyond traditional RF antennas. Ground stations may increasingly communicate with satellites using various methods, including optical or other advanced technologies.

In countries where ground station operations have been extensively conducted for decades by public and/or private organizations, specific laws and regulatory processes exist. Operators may be required to apply for permits or licenses for their ground stations. For example, in Germany, a license is required for transferring satellite data. Conversely, in Sweden, controlling a satellite is the basis for needing a license, meaning that owning an RX ground station does not require a license. Additionally, the location of the mission control center may determine the need for a ground station permit. For instance, if the control center is based in Canada, a local permit is necessary, and regulations also cover the distribution and security of raw data.

In Japan and the USA, comprehensive regulatory frameworks exist, including processes for validating and auditing ground stations. In South Africa, the permit required is a generic electronic communications service license, while China has its own licensing processes in place. In India, the licensing process is handled by the national one-stop shop space agency.

Apart from specific ground station regulations, a TX permit is needed for the uplink frequency in many countries. Some countries primarily regulate radio licenses and do not have a licensing process specifically for ground stations. For example, in the UK, the Republic of Korea, Ukraine, Bulgaria, Kazakhstan, Spain, and France, only a TX permit is required. Norway follows a similar approach, except that a ground station license is required if the station is located on Svalbard or Antarctica.

In addition, there is a group of countries that do not require a specific ground station license but mandate additional steps alongside the TX permit mentioned earlier. For example, in the Czech Republic, both

RX (downlink) and TX (uplink) require licenses, meaning that a ground station in the Czech Republic always requires a license. Nevertheless, the process is reportedly fast and inexpensive. In Italy, individuals must file a notification to become a tele-operator. This filing takes effect immediately and is free of charge, with annual fees collected only if sales income exceeds €500,000 per annum. Operating in France necessitates an advance notification of the distribution of satellite data. Similarly to some other countries, attention is given to the security of data, which could be harmful if accessed by unauthorized parties.

The differences between countries in the anticipated or estimated speed of the radio permit process, as reported by respondents, were striking, ranging from two days to one year. The shortest estimates came from the UK, where the process has taken as little as two days. However, it's noted that if shared spectrum usage requires consultation with other stakeholders or if the satellite class needs approval by the Ministry of Defence, the process can extend to 2–3 months. At the other end of the spectrum is the USA, where the process may take up to 9–12 months and can involve multiple cycles of application submission and clarification.

It's also observed that announced permit process times are often exceeded in reality. For example, in Italy or South Africa, the official 60-day time frame is rarely met, and the process may extend beyond 6 months. This, of course, introduces uncertainty into the business operations of ground station operators. Additionally, some respondents noted that the process and its progression are "somewhat opaque," further adding uncertainty and undermining the predictability of business operations.

4.1.2 General and Hidden Regulations Affecting Ground Stations

As noted earlier, numerous types of general national and regional regulations that must be taken into consideration when commencing ground station operations. These include obtaining building permits, addressing occupational health considerations, adhering to export restrictions, and ensuring compliance with environmental impact regulations.

Imported equipment must also adhere to trade restrictions and possess necessary certifications, such as the CE mark in the EU, UL certification in the USA, and Great Wall certification in China or the Type Approval required in South Africa for imported devices that transmit a signal. Depending on the country and the project, consultation with aviation, security, or defense authorities may be necessary. This is sometimes linked to hosting equipment for a foreign party. Furthermore, when operating on non-commercial radio-amateur bands, operators are required to obtain a HAREC license.

In summary, general regulations typically do not overly complicate the construction or operation of ground stations, as they are generally predictable and transparent. However, the same cannot be said for the hidden regulations mentioned earlier. These are often neither predictable nor transparent. Delays in the permit processes may indicate security evaluation procedures in connection with the ground station operator or its clients. According to several respondents, other ministries and regulatory bodies may be invited to participate in the process on a case-by-case basis. At its worst, this may result in unfair favoritism toward certain applicants.

At the same time, it's worth noting that opinion letters, decisions, or even participants in these discussions may be classified. Based on the authors' experience, the interviewees' responses, and desk study, there appears to be widespread variation between countries in the stringency of these classification processes. Overall, satellite data is increasingly recognized as a valuable and even strategic asset, the distribution of which must be controlled by nation-states. Nonetheless, this contrasts with the fact that remote sensing satellites do not recognize country borders—they sense remotely wherever they are programmed to and download their data wherever they can, whether it's in their home country or a friendly foreign country.

4.2 Foreign Operators and Foreign Operations

In general, most countries allow foreign entities to own and operate satellite ground stations on their soil, provided they comply with local regulations similar to domestic entities. Only two of the countries inspected, namely China and the Republic of Korea, explicitly block foreign ground station operations within their borders. However, China does allow ground stations for foreign embassies and Non-Governmental Organizations with special permission. In some other countries, such as Japan and South Africa, establishing a local entity for compliance is required, while in others it is merely recommended. Nevertheless, the situation is somewhat unclear in several of the countries studied, as there are no prior cases on this matter. It's worth noting that foreign entities operating inside the USA must pay market access fees, with the highest fees imposed on foreign entities serving foreign satellites.

It should be noted that sharing capacity with peers—or even competitors—in other countries or hosting foreign peers' ground stations in one's "antenna farm" is more or less an industry standard in new space ground station companies. This is much easier for foreign peers than the alternative of acquiring real estate, organizing local maintenance, and navigating regulatory processes in all the target countries, which may be several. These business models—hosting and co-locating—are inherently international, but rules and regulations on these practices are largely underdeveloped.

A local ground station operator may also want to operate ground stations in other countries. This is mostly unregulated in their home country; hence, the main concern is to comply with the local regulations of the target country. Some countries require notifications to be made to the home country regulator. Additionally, in Italy, revenues generated in foreign countries are added to the calculation when revenue-dependent permission fees are calculated. Interestingly, China and the Republic of Korea allow their companies and citizens to operate ground stations in other countries.

It should be noted, however, that some countries do not differentiate whether the actual ground station is located within the home country of the company or elsewhere: as long as the mission control center is in the USA, Canada, Germany, or Sweden, one must obtain a ground station operations permit in the respective country and comply with the regulations when applicable—in addition to adhering to the local regulations of the country where the ground station is situated. Hence, it is possible that the ground station operator does not have any ground stations in its home country but still has to comply with its ground station regulations.

Based on the findings, it seems evident that regulations regarding foreign entities building, owning, or operating satellite ground stations in other countries have room to evolve in the coming years as new kinds of cases needing regulation emerge in various countries.

4.3 Comparing and Harmonizing with Other Countries

When comparing their country to others, some respondents express modesty in their opinions, often stating that they do not know enough about other countries to make a sensible comparison. Additionally, there were misconceptions, such as expecting that all countries have similarly strict rules as the respondent's home country. These findings reveal that the perspective of ground station operatives is often local, without considering global or cross-border factors.

Many of the operators have their own global antenna networks and work more internationally, making them more capable of assessing how their local environment may differ in a global comparison. Nevertheless, regardless of the respondent, there was significant support for global harmonization of regulations, with some caveats and several opportunities identified. The newness of LEO satellites and constellations, coupled with the inexperience of regulators in regulating them, was seen as one of the primary challenges. Therefore, suggestions were made to adjust local regulations and educate regulators to accommodate LEO satellites.

> In the case of small satellites (nanosatellites, CubeSats), regulation is lagging behind with the reality.

> Regulators are not familiar with Satellite RF reality, the pace of launches of small satellites, the needs of satellites and the ground segment-as-a-service business model.

Operating with GEO satellites may be considered a relatively straightforward and "rigid" business, compared with LEO satellites, which are inherently more dynamic. LEO satellites have the capability to obtain remote sensing data from virtually all parts of the world. They do not "honor" the borders, and constellations may grow from small to large over time, while regulated parameters generally remain consistent.

> Regulations must take a global approach as LEO satellites are not restricted to any one geography.

One respondent complains that their country's regulation is loose and partially undetermined, which brings uncertainty to the process. In some other countries, the regulator is more helpful, and regulations are more rigid yet transparent. This may also result in negative regulatory decisions, but even that may be better than not having the decision in a sensible time frame.

> Regulations are lax, but uncertainty does not help operating. … In other countries there's more precision and, even if that might mean getting 'No' as an answer, at least we know why and in a timely manner.

Lengthy process times were also mentioned in some responses, particularly concerning uplink frequency applications, which necessitate filing through the International Telecommunication Union (ITU) process first. Overall, the timeline, coupled with the successive order of the ITU and local permit processes, is seen as problematic.

> It is time to think about a better approach to the ITU frequency coordination process in combination with ground stations.

Part of the responsibility is also assigned to satellite operators themselves.

> I feel that satellite operators sometimes focus on the satellite and overlook the ground side and some regulations. So, I think it is important for GSaaS operators like us to inform them about this.

Based on the responses, the most pressing area for improvement is the regulation of uplink frequencies. While these frequencies are regulated by the ITU on the satellite end, they are regulated nationally on the ground station end. This discrepancy is viewed as a significant challenge, particularly since LEO satellites require consistent data uplink across all countries where they are supported by ground stations.

> Better harmonization of ground space spectrum would help.

> Harmonization should follow in particular for bands usage. It would be great if all would accept the same bands at the same conditions for TT&C.

Recipients also perceive clear risks in harmonizing regulation if not done properly. The goal should be to establish an enabling governance system that prioritizes the efficiency of both operation and administration. Therefore, existing best practices should be identified and utilized as a foundation, with input from the industry being sought from the outset. Merely amalgamating all regulations together would result in additional bureaucracy, potentially undermining many, if not all, nations—a scenario detrimental to the space sector's needs.

> Before harmonization, sharing best practices would be great. Regulators should be open to hear how other countries are doing things.

> Yes, if said harmonization results in more flexibility in setting up and licensing ground station, and not making it difficult!

> While we would like to see standards between countries in ground station regulation, we fear that a 'one size fits all' approach will burden smaller countries with significant red tape.

Permits should not be regarded as a source of income for the government, as the primary purpose of regulation is to prevent interference. Therefore, market entry fees, for example, are viewed as a net negative, potentially resulting in loss of business and distorting market development. Another objective of regulation is, or should be, cybersecurity, which ought to be integrated into all operations.

> Regulators should not look to regulatory fees as a revenue source and should keep them as low as possible to encourage economic development in the space industry. Market access fees for international satellite operators is a net negative.

> Cyber security compliance must be built into the regulations to ensure safe and trustworthy international ground station operations.

Respondents advocate for greater harmonization in ground station regulation and recognize numerous benefits for all parties involved: enhanced resource utilization, reduced interference, fair competition, and decreased compliance costs, among others. The focus should be on creating an enabling environment rather than imposing restrictions, while ensuring the visibility of both national and global rules and benefits.

> Regulations and the costs related to ground station licensing differ greatly from country to country. This has a significant impact on the operation and cost of deployment of satellite constellations, so global harmonization is a key element to expanding the space industry.

> It's a global market with global customers. Think all would gain to get a more harmonizing regulation, with aligned processes and cost procedures. It could potentially also lead to better overall structure and control.

> Efforts to harmonize regulations for satellite ground stations globally hold several key advantages. Standardized rules enhance spectrum efficiency, reduce compliance costs, and encourage the development of seamless global connectivity. This approach facilitates innovation, attracts investment, and mitigates cross-border interference issues. Additionally, global regulations ensure adherence to environmental and safety standards and promote international cooperation in addressing shared challenges. While achieving global harmonization may present challenges, the potential benefits for the satellite industry and its stakeholders are substantial.

In contrast, respondents also express concerns regarding the utilization and sharing of resources. The vast sizes of constellations, gaps in reception coverage, and unhealthy competition stemming from regulatory disparities are identified as potential hazards. These factors may contribute to an unoptimized global system and congestion of frequencies, which are globally limited and scarce resources.

According to the findings of this study, a certain level of harmonization of satellite ground station policies and regulation would be beneficial to the space sector. It would help operatives in getting the required resources and licenses to operate their constellations and thus provide the space community the core ingredient of their services: the data. Harmonization could improve the coordination and use of scarce resources, such as the frequencies and orbit space. When done right, harmonization would also improve the security of the satellites and their data, not forgetting the security needs of participating nations.

5 Discussion and Conclusions

Based on the findings, it is evident that there is support as well as a clear need for global harmonization of regulations governing satellite ground stations across different countries. Best practices should be defined through an open process, shared, and implemented globally. However, it is important to recognize that one size does not necessarily fit all: countries vary greatly in terms of the age, nature, and size of their space sectors.

The nature and resourcing of national regulatory bodies should also be considered. It is essential to assess the key skills required and the objectives given to regulators, especially if they were not initially established for space administration. Creating common regulations and enforcing them through administrative offices ranging from the Ministry of Education to the Ministry of Transportation, and from the Office of Security and Defense to the ITU, may not yield the best results, especially given the current scarcity of resources. However, a multidisciplinary approach may prove fruitful if implemented intentionally.

It should be noted that developing regulation and processes on ITU internationally and harmonizing ground station regulations on national level are two separate issues. The role and importance of the ITU in current regulation and its development are clearly acknowledged. However, changing regulatory frameworks is recognized as a lengthy process, and there is uncertainty about whether all nations would consistently adhere to common rules. Sanctions are typically needed to enforce regulations, but as sanctions do not exist in this context, it is unsurprising that some nation-states have their own rules for international operations.

Given these challenges, a mutually agreed-upon set of recommendations, perhaps with tier levels, might be preferred over applying one strict set of rules universally. Compliance with these recommendations could lead to an ITU speed lane, resulting in a more streamlined regulatory process in participating countries. In addition to aspects regarding satellites and ground stations, these rules should also address cybersecurity issues.

The outcome of this study carries a subtle tone of warning, suggesting that action is needed before the situation becomes uncontrollable. The increasing congestion of orbits, coupled with the uncontrolled creation of space debris, is reminiscent of the development of climate change: it was recognized early on, but action was not taken until its reality forced nations and the international community to act.

The underlying sentiment of respondents appears to advocate for sensible, common regulation to conserve and ration the scarce resource known as space. Specifically, the frequencies required to uplink and downlink data to and from satellites and other spacecraft should not be overutilized in a short-sighted manner, as this would limit their usability in the future. Such conservation efforts would be to the benefit of all parties involved: nations, the world, and space itself.

6 Appendix 1. Email Questionnaire

- Which country are you answering for?

- Which key laws in your country need to be taken in consideration specifically in satellite ground station operation?
- Do you need a permit to own or operate a ground station in your country? If yes, describe the process with few sentences, including cost and timeline.
- Do you need permits for radio TX or RX? If yes, describe the process with few sentences, including cost and timeline.
- Do you need other permits, such as export permits?
- Can foreign parties own and operate ground stations in your country? How are they regulated?
- Can you own satellite ground stations in other countries? How is this regulated by your country?
- How would you compare your country to others as a base for satellite ground stations?
- Do you think we should put effort in harmonizing the regulation in different countries and putting global regulation in place? Please elaborate?
- Any thoughts you would like to share about the topic—regulation of ground stations and space in general in various countries?
- Please give your name, title, and organization.
- We would like to add you to the list of contributors, listing your name, title, and organization. Is this ok for you?

7 Appendix 2. List of Participants

- Bulgaria: Sfera Technologies
- Canada: Estelle Chou, Senior Policy and Licensing Office, Global Affairs Canada, Government of Canada.
- China: Jingdong Xue, freelance Chinese aerospace expert
- Czech Republic: Groundcom.space
- Finland: Dr. Tommi Rasila, Founder and chairman, NorthBase Oy
- India: Kiran Sharma
- Italy: Matteo Cappella, Regulatory Affairs Specialist, Leaf Space
- Japan: Hiromu Inoue, Sales Engineer, Infostellar, Inc.
- Kazakhstan: Identity withheld
- Republic of Korea: Kihwan Choi, Manager, CONTEC Co., Ltd.
- South Africa: Stefan de Klerk, CFO, Pink Matter
- Sweden: Arctic Space Technologies

- UK: Dr. Paul Crawford, Director, Dundee Satellite Station Ltd.
- Ukraine: Identity withheld
- USA: Ronald Faith, President and COO, RBC Signals
- Tanzania: Leonard Shayo, Founder & CEO, Olduvai Space Center (OLSPACE)

8 Appendix 3. Desk Study Material

- Remote Sensing Space Systems Act (CAN): https://laws-lois.justice.gc.ca/eng/acts/R-5.4/FullText.html
- Remote Sensing Space Systems Regulations (CAN): https://laws-lois.justice.gc.ca/eng/regulations/SOR-2007-66/FullText.html
- French Space Operations Act, No. 2008–51 (F): https://www.legifrance.gouv.fr/loda/id/LEGITEXT000018939303/
- LOI N° 2008-518 DU 3 JUIN 2008 RELATIVE AUX OPÉRATIONS SPATIALES: https://www.legifrance.gouv.fr/loda/id/LEGISCTA000045223235
- Act to give Protection against the Security Risk to the Federal Republic of Germany by the Dissemination of High-Grade Earth Remote Sensing Data (D); https://www.unoosa.org/documents/doc/spacelaw/national/germany-satdsigGE.doc
- Dunk, F. (2001). Vikings first in national space law; Other Europeans to follow: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1038&context=spacelaw
- Updated report on the voluntary implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities in Norway (N): https://www.unoosa.org/res/oosadoc/data/documents/2023/aac_105c_12023crp/aac_105c_12023crp_21_0_html/AC105_C1_2023_CRP21E.pdf
- Royal Decree No. 278/1995 (E): https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/spain/royal_decree_278_1995E.html
- Independent Communications Agency of South Africa (RSA): https://www.icasa.org.za/
- Code of Federal Regulations (USA): https://www.ecfr.gov/current/title-47/chapter-I/subchapter-B/part-25

- Hallituksen esitys eduskunnalle laeiksi maa-asemista ja eräistä tutkista sekä avaruustoiminnasta annetun lain muuttamisesta ja sakon täytäntöönpanosta annetun lain 1 §:n muuttamisesta; https://www.finlex.fi/fi/esitykset/he/2022/20220113

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