WRC-19: New space law enabling the sustainability of LEO

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CONFERENCE PAPER

1. ABSTRACT

Low Earth Orbit (LEO) is becoming increasingly crowded. As the first popularly called "megaconstellations" of hundreds or thousands of small satellites are launched, an increasing number of even smaller satellites are also entering LEO from newly emerging spacefaring nations, among other actors. One intergovernmental organization, the International Telecommunication Union (ITU), is addressing regulatory challenges raised by these innovations while seeking to preserve the sustainability of LEO – all within the framework of the Outer Space Treaty and the limits of its own mandate.

This paper highlights notable actions by the ITU's 2019 World Radiocommunication Conference (WRC-19) where Member States adopted innovative new international regulations to balance the introduction of new technologies and services in space whilst ensuring the observation of existing international legal norms within the Union's purview.

The Final Acts of WRC-19 are a treaty agreement that is incorporated into the ITU's international Radio Regulations. The next WRC is scheduled for 2023, will continue this cadence of international law making in response to technology innovation and the needs of its Member States. Thus, space law is undergoing continuous creation and evolution at this small United Nations organization – a possible model for others to follow.

2. THE NEW RUSH TO LEO

It seems that nearly every week, another news story breaks about the launch, licensing, or other development concerning some Non-Geostationary Orbit (NGSO) satellite system destined for Low Earth Orbit (LEO). Recent examples include SpaceX's steady cadence of launches of large batches of small satellites to populate its Starlink system with the initial six-hundred already in LEO (of the 12,000 authorized) with a mission to provide a high-speed Internet service [1]. In July, 2020, the United States' telecommunications regulator, the Federal Communications Commission (FCC), authorized Amazon.com to deploy and operate its proposed Kuiper Systems NGSO constellation comprising 3,236 satellites also for the purpose of delivering broadband services [2]. Meanwhile, after declaring bankruptcy in March – with 74 of 720 originally planned satellites installed in LEO – the assets of WorldVu's OneWeb constellation [3], the company that kicked off this second generation gold rush in 2016, were purchased by a consortium of the Government of the United Kingdom and Bharti Global Limited, an Indian telecommunications operator in July [4]. And, if that weren't quite enough news, proposals for many, many more satellites have been announced. In response to an FCC notice setting a May, 2020 cut-off date for the consideration of additional NGSO system applications, proposals for systems amounting to another 84,000 satellites were submitted [5], including an application from SpaceX for a second generation system consisting of 30,000 additional satellites [6] and a request from OneWeb, despite its bankrupt status, for a "Phase 2" system of another 47,000 satellites [7]. Proposals were also submitted by Telesat (adding 1,373 satellites), Kepler (360), ViaSat (268), SES for its O3B system (70), EOS Defense Systems for its Audacy system (3), New Spectrum for its Pleiades system (15), and new applicant Mangata Networks (791) [8].

OneWeb, SpaceX, Amazon, and most of the others plan to provide connectivity to the planet, including to people who live and work in the remote and rural areas where terrestrial telecommunications systems fail to reach – and may never reach. This was also the vision of the original proponents of large commercial NGSO systems in the 1990s and early 2000s such as Iridium, Teledesic, and SkyBridge. These projects paralleled the development of the mobile telephony industry, the rise of the Internet, the advent of smart phones, and the introduction of mobile broadband – as it has become essential to social engagement, entertainment, business, social services, and sustainable development. And if it weren't evident before, in a world experiencing the ravages of a prolonged pandemic, the criticality of broadband connectivity is even clearer as the critical link to remote working, education, health-care, and the outside world. This insatiable and growing appetite for connectivity isn't limited to people and enterprises but includes a growing number of machines and devices whose successful operation require interconnection to one another (machine-to-machine (M2M)) and to the Internet (Internet of Things (IoT)). The traditional narrowband communications functions such as monitoring, texting, and paging are also still in play. These emerging narrowband, less latency-sensitive requirements have inspired another host of new NGSO constellation proposals, many using very small satellites such as cubesats. Examples include Kepler (as originally announced) [9], Swarm [10], and Myriota [11], which build on a tradition established by the ORBCOMM system in 1999, which remains in operation with new generations of satellites.

LEO, of course, is also the home of the International Space Station as well as a diverse range of satellite networks and systems providing essential services such as navigation, earth observation, radar, surveillance, and other scientific and military purposes. Moreover, an increasing number of small sats from a growing number of space-faring nations, as well as universities and research institutions and commercial companies, are adding to the population of LEO. The 2020 State of the Satellite Industry Report observed that there was a total of 2,046 satellites in orbit from 75 nations as of December 2019, a 77% increase over the past five years due in large measure to the launch of small satellites (less than 1,200 kg) [12].

The latest rush to LEO is not only responsive to the surging market demand for high-speed broadband connectivity universally across the planet, including the high seas, the poles, in flight, and other remote areas. It is also being driven by issues of scarcity and priority. Although NGSO operators don't appear to face the same challenge as their brethren in Geostationary Satellite Orbit (GSO) with respect to limited availability of orbital slots, access to LEO in the most desirable altitudes becomes increasingly difficult to coordinate as the overall number of systems, satellites, and orbital planes that are proposed and deployed grows.

It is not only a question of physical space, but one of availability of radiofrequency spectrum -- the ability to successfully close radio links with other satellites in the system or with earth stations below. With so many satellites operating in so many altitudes and orbital planes, the challenges of spectrum capacity and harmful interference will be joined by another – the potential for in-line events in which a satellite's radio line-of-sight to an intended receiver on earth or in orbit is eclipsed by another satellite passing by.

Yet another driver is priority. The global regime for managing access to the orbit for these systems is a priority-based system under which the first mover can receive priority to accessing the resource relative to later-filed systems. Under this "first-come/first-served" system, later-filed systems must coordinate their use of spectrum and orbits with earlier higher-priority systems, which will likely prove more difficult as the number of systems and satellites in operation grows. This global system of priority and coordination is maintained by a small specialized United Nations organization, the International Telecommunication Union (ITU) [13].

It is a gross understatement, especially to an audience of astronomers and other space experts, to say that this accelerating growth of LEO filings raises serious concerns about long-term space safety and sustainability. These concerns are not limited to orbital debris mitigation and managing all that space traffic, but extend to the fear of filling our skies with shiny hardware ruining everything from casual stargazing to optical astronomy observations and even overwhelming radio astronomy observatories with radio interference. Another concern is whether these massive proposed systems occupation of particular obits – to the possible exclusion of others -- amounts to an appropriation of the orbit on contravention of the Outer Space Treaty [14].

Some, but not all of these issues, are beginning to be addressed by national regulators as they license these systems. In the U.S., under the direction of the National Space Council, NASA and other federal space operators updated their Orbital Debris Mitigation Standard Practices in late 2019 [15], and the FCC proposed far-reaching new orbital debris rules on private NGSO systems in April, 2020 [16]. Global efforts to adopt sustainable space practices were forged by the United Nations' Committee on Peaceful Uses of Outer Space in 2018 [17]. Even the very proponents of these megaconstellations raise concerns regarding the sustainability of LEO and promote their own safety measures [18] [19] [20].

The ITU, too, is facing challenges as it performs its role in managing the sustainability of radiofrequency and orbital resources that support global space activities in light of the burgeoning number of NGSO systems and satellites planned. The sheer number and complexity of the proposed systems with their large number of orbital planes and satellites far surpasses the regulatory systems, processes and procedures that were designed to manage access to these resources. At the same time, ITU Member States, particularly new space-faring nations have been demanding reforms to the ITU's regulatory procedures to enable small satellites. Still others are looking to the future and seeking to establish the regulatory regime that will enable the next generation of satellite networks and services. The ITU and its membership recently dealt with these issues at a treaty conference, the 2019 World Radiocommunication Conference (WRC-19), in Sharm el-Sheikh, Egypt, culminating in new space law provisions responding to these growing concerns.

Fig. 1: Illustration of the original OneWeb LEO NGSO system.

3. THE ITU'S ROLE IN MANAGING LEO

The ITU was created in the 19th century to enable the interconnection and promote the development of telegraph systems across national boundaries. It was then called the International Telegraph Union. With the advent and growth of radio systems, the need for regulation of that technology became apparent as needed radio operations were often overwhelmed from destructive interference caused by the uncontrolled radio operations of other users. The need for regulation and international cooperation on radio use was also indicated by its growing role in the operation of ships at sea. In 1906, a conference of nation states agreed to form the International Radiotelegraph Union to establish international technical regulations, the Radio Regulations, providing harmonized guidance on radio use. In 1912, the sinking of the *Titanic* and the tragic loss of human life that resulted drove nations to take stronger actions to enable the effective use of radio spectrum and the operation of radio stations on ships to promote safety at sea [21].

National regulations were also undertaken to manage domestic use of radiofrequency spectrum and to implement the new international arrangements. In the United States, the Department of Commerce's Bureau of Navigation initially performed this role [22]. As radio services and usage began to proliferate, including the introduction of radio broadcasting, Congress established the Federal Radio Commission in 1927, the predecessor to the FCC [23].

After World War II, the ITU (which by then included the radio union and was named International Telecommunication Union) joined the new United Nations (UN) system in 1947. Its headquarters were moved from Bern to Geneva, Switzerland (and its operating language from German to French), where it neighbors the UN's European Headquarters. As telecommunication (including radiocommunication) technology and services continued to evolve and expand, so did the ITU's areas of work, which eventually extended to space communications beginning in 1959 [21].

The ITU's governing instruments recognize that it is the sovereign right of each State to regulate the telecommunications services within its territory and "the growing importance of telecommunication for the preservation of peace and the economic and social development of all States." The ITU's purpose is to "maintain and extend international cooperation among all its [193] Member States for the improvement and rational use of telecommunications of all kinds." And includes "to promote the extension of the benefits of the new telecommunication technologies to all the world's inhabitants" [24]. The fundamental tenets pertaining to radio are set forth in Article 45 of the ITU Constitution: "Harmful Interference:"

> All stations, whatever their purpose, must be established and operated in such a manner so as not to cause harmful interference to the radio services or communications of other Member States or of recognized operating agencies, or of other duly authorized operating agencies, which carry on a radio service, and which operate in accordance with the provisions of the Radio Regulations [24].

This oversight of radio services extends to those operating in space, including satellites in Earth orbit. Article 44 of the Constitution contains two special provisions on the "Use of Radio-Frequency Spectrum and of the Geostationary-Satellite and Other Satellite Orbits":

1. Member States shall endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end, they shall endeavour to apply the latest technical advances as soon as possible, [and]

2. In using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries [24].

The ITU's Radio Regulations contain a vast array of detailed technical regulations describing the agreed use of radio spectrum internationally, including allocation of particular frequency bands to defined radio services with common purposes and characteristics; limits on those operations in particular allocations; allotment and assignment plans to reserve capacity for every country for some services; first come/first served procedures for recording frequency assignments. The current version of the Radio Regulations consists of four volumes amounting to some 2,000 pages [25].

The Radio Regulations define more than a dozen satellite services, in addition to the space research and radio astronomy services, and allocate bands of radiofrequency spectrum and conditions for their use. The procedures for coordinating most satellites are defined in Articles 9 and 11 of the Radio Regulations which provide a detailed timeline and steps for coordinating, notifying, and recording the frequency assignments that comprise a satellite network or system (of multiple satellites) in the ITU's Master International Frequency Register. Satellite filings are processed by the ITU's Radiocommunication Bureau in their order of receipt. The receive date controls priority rights to the resources should the proponent successfully complete the ITU's processes, including bringing into use the operation within seven years of the receipt of its initial filing. No. 8.3 of the Radio Regulations provides that: "[o]nce recorded in the Master Register with a favorable finding, frequency assignments shall have the right to international recognition …. . This right means that other administrations shall take it into account when making their own assignments, in order to avoid harmful interference" [25]. Article 22 of the Radio Regulations contains additional requirements for Space Services and sets limits for controlling interference between GSO networks and NGSO systems.

Although the Radio Regulations originated more than a century ago, they are regularly updated by ITU World Radiocommunication Conferences (WRC) which normally are convened every four years. WRCs are attended by delegations of Member States as well as Observers without decision making authority (including satellite operators who participate as "Sector Members") following almost four years of preparations. WRCs conclude Final Acts containing revisions to the Radio Regulations, which are a component of the ITU's basic legal instruments. Thus, to the extent the Radio Regulations address space systems and services, and the rights of States to access the orbits, they are part of the body of space law. And, the good news is that new space law is being developed to accommodate innovation and to tackle challenges that are arising, including addressing the massive increase in filing of large and complex NGSO satellite systems.

Fig. 2: WRC-19 plenary in Sharm el-Sheikh Egypt. Photo courtesy of ITU

4. WRC-19 INNOVATIVE ACTIONS ON LEO

On the shores of the Red Sea, delegations from 163 ITU Member States gathered for four long weeks in late 2019 to consider 2,500 proposals to revise the Radio Regulations, which had last been updated in 2015. WRC-19 was attended by 3,420 delegates – the largest WRC in history [26]. The Final Acts of the Conference contain more than 550 pages, including new regulatory procedures and an entirely new mechanism for managing large NGSO systems; streamlined procedures for small satellites (in ITU parlance, satellites with short duration missions); and a new approach for sharing between geostationary satellite networks and NGSO systems in the next frequency range beyond Ka-Band for communications satellite development [26]. These new provisions of space law are described briefly below.

A. New Approach to Managing NGSO Satellite Filings

In 2015, the previous WRC briefly considered the emerging challenge looming over the ITU's historic regulatory regime for managing orbital and spectrum resources that was posed by the growing number of filings for very large NGSO constellations. The Director of the ITU's Radiocommunication Bureau compared the situation to an earlier crisis from the 1990s when the ITU was overwhelmed by rampant filings for GSO networks, many submitted for speculative or anticompetitive reasons (*i.e.,* "paper satellites"), making it impossible for the Radiocommunication Bureau to timely process them and for the parties to complete required coordination [28]. The ITU addressed the issue through a series of regulatory, financial, and administrative measures adopted by a series of Conferences and meetings and included shortening the regulatory period for bringing into use from nine years to seven; introducing cost recovery fees for processing satellite filings; and requiring submission of due diligence information about the network to provide the Bureau and other parties data to assess the authenticity of the claims to the spectrum/orbital resources [21].

The United Kingdom and United States, the notifying administrations of some of the newly proposed NGSO systems (including OneWeb and SpaceX), submitted proposals to WRC-15 seeking adoption of new regulatory requirements for coordinating and managing these emerging NGSO systems. However, the proposals had been developed at the very end of the four-year preparatory cycle and had garnered insufficient support from other nations. Moreover, the delegates were concerned that the complex endeavor of crafting new regulatory solutions could not be done well on the fly. Thus, they agreed to spend the next four years developing a workable regulatory solution that would be ready for approval by WRC-19 and would address both the definition of bringing into use NGSO systems and the introduction of a milestone-based approach to the Radio Regulations. [29]

Bringing into Use. In order to obtain international recognition of a frequency assignment to a space station of a satellite network, it must be "brought into use" by the expiry of the regulatory period of seven years. The Radio Regulations have long provided a definition of what this concept of "bringing into use" means, at least for GSO networks (from No. 11.44B of the Radio Regulations):

> A frequency assignment to a space station in the geostationary-satellite orbit shall be considered as having been brought into use when a space station in the geostationary-satellite orbit with the capability of transmitting or receiving that frequency assignment has been deployed and maintained at the notified orbital position for a continuous period of 90 days [25].

However, the Radio Regulations lacked any definition for bringing into use the frequency assignments for the space stations comprising a NGSO system. In the absence of a regulatory provision, the Bureau applied a working definition based on the launch of a single satellite of an NGSO system as the baseline requirement for the bringing into use. Some thought that this set too low a threshold to establish implementation of the entire system and to deserve regulatory protection for the whole system as described in its ITU filings. For example, the United Kingdom (on behalf of OneWeb) had proposed in 2015 that the required number of satellites for bringing into use an NGSO system should be based on a percentage of the total number of satellites comprising the system. This would more clearly indicate actual progress of the notified system in implementing its proposal and be a fairer determination of actual use of the resources that had been reserved with the filing of the system with the ITU.

During the WRC-19 preparations another view emerged, as was captured in the Conference Preparatory Meeting Report:

> [I]t would be unrealistic to expect to have all the satellites of a system, in some cases consisting of hundreds or thousands of satellites, to be deployed within this seven-year regulatory period. Therefore, the BIU [bringing into use] of frequency assignments of non-GSO systems cannot always be considered as a confirmation of the full deployment of these systems, but instead may in some cases be just an indication of the commencement of deployment of satellites capable of using the frequency assignments [30].

Thus, a second, new approach would be needed to gauge the implementation of these large systems beyond the 7-year regulatory period. WRC-19 decided to retain the bringing into use construct and to establish a clear definition for application to NGSO systems, No. 11.44C, based on the launch of a single satellite that must operate within the orbital and frequency parameters of the system as described in the filing:

> A frequency assignment to a space station in a non-geostationary-satellite orbit network or system in the fixed-satellite service, the mobile-satellite service or the broadcasting-satellite service shall be considered as having been brought into use when a space station with the capability of transmitting or receiving that frequency assignment has been deployed and maintained on one of the notified orbital plane(s) [footnote omitted] of the non-geostationary

> satellite network or system for a continuous period of 90 days, irrespective of the notified number of orbital planes and satellites per orbital plane in the network or system. The notifying administration shall so inform the Bureau within 30 days from the end of the 90-day period [footnotes omitted] On receipt of the information sent under this provision, the Bureau shall make that information available on the ITU website as soon as possible and shall publish it in the BR IFIC subsequently [26].

A new element to the provision is the publication of the information on the ITU's website and regulatory publications to increase transparency and to ensure that others are able to monitor the implementation of the system.

Milestone-Based Process. In application of the Outer Space Treaty, the Radio Regulations require that satellite operators, even though they will provide services from outer space (which is not the territory of any country) to the territories of multiple countries, must obtain a license from a single country to authorize operation of its space station or stations, in the case of a NGSO system. The licensing state will typically also serve as the operator's representative, or "notifying administration," to the ITU. The notifying administration will represent the satellite operator in the ITU's processes, including submission of satellite filings such as coordination requests and notifications to the Radiocommunication Bureau culminating in the recording of the frequency assignment in the Master International Frequency Register. Some national administrations that license commercial satellite operators have instituted various approaches into their domestic regulations to ensure that planned systems are actually implemented so that their promised services are provided to the nation and to prevent warehousing of spectrum and orbital resources. These approaches include a milestone-based approach.

The FCC's milestone requirement is to require launch and operation of the network within six years of the grant of the license. In 2017, the FCC decided to relax this requirement for NGSO systems "to afford operators greater flexibility with system design and implementation, in light of proposals to launch and operate thousands of satellites [31]." The FCC adopted a two-step milestone requiring 50% of the constellation to be operational six years after grant of the license, and the remaining 50% completed by the following three years.

At WRC-19, the delegations agreed that a milestone-based approach that would allow NGSO systems to be fully implemented a number of years beyond the seven-year regulatory period, with performance milestones comprising objective standards, including percentage of completion at set timeframes, would both incentivize the notifying administration to timely deploy the systems and services and "provide a balance between [*sic*] the prevention of spectrum warehousing, the proper functioning of the coordination mechanisms, and the operational requirements related to the deployment of the non-GSO system." Moreover, this new approach would "help ensure that the Master Register reasonably reflects the actual deployment of such non-GSO satellite systems. . . and improve the efficient use of the orbital/spectrum resources [27]." In other words, this new milestone-based approach will promote more sustainable consumption of the spectrum/orbit resource.

Letter symbols	Space radiocommunications	
	Nominal designations	Examples (GHz)
L	1.5 GHz band	1.525-1.710
S	2.5 GHz band	2.5-2.690
C	4/6 GHz band	3.4-4.2 4.5-4.8 5.85-7.075
Ku	11/14 GHz band 12/14 GHz band	10.7-13.25 14.0-14.5
Ka	20 GHz band 30 GHz band	17.7-20.2 27.5-30.0
V	40 GHz band	37.5-42.5 47.2-50.2

Table 1: Nomenclature of the frequency and wavelength bands used in telecommunications [32].

The overall concept of a milestone-based approach was readily agreed by WRC-19, but achieving consensus on the myriad details was tremendously difficult, including the percentages and timeline of the milestones, which services and frequency bands they would be applied to, and transitional measures – their retroactive application to pending systems. However, all agreed that a solution could not be postponed until the next Conference in light of the continuing volume of large filings being received. The resulting agreement is contained in new Resolution 35, "A milestone-based approach for the implementation of frequency assignments to space stations in a non-geostationary-orbit satellite system in specific bands and services" (Sharm El-Sheikh, 2019) and a new Radio Regulations provision (No. 11.51) that incorporates by reference its provisions into the treaty. The new approach applies only to NGSO systems in the communications services – Fixed-Satellite, Mobile-Satellite, and Broadcasting-Satellite Services in the most congested commercially used frequency bands: Ku, Ka, and V-Bands [see Table 1].

The first step of the new milestone-based procedure requires NGSO systems subject to the Resolution to submit deployment information to the Radiocommunication Bureau thirty days from the expiry of their seven-year regulatory period providing satellite system information, launch information, and space station characteristics for each space station deployed. This information will be made available as received on the ITU's website and in its regulatory publications.

1st Milestone	7 + 2 years	10%
2nd Milestone	7 + 5 years	50%
3rd Milestone	7 + 7 years	100%

Table 2: NGSO System Milestones from Resolution 35 (Sharm el-Sheikh, 2019) [27].

For systems that are not fully implemented, the next step of the process as shown in Table 2 requires the notifying administration to submit updated deployment information two years later indicating that at least 10% of total satellites have been deployed. Then the same process applies for the next two milestones: three years later, when the system should be at 50% deployment, and finally two years after that, when the system should be 100% complete. At each stage, the Radiocommunication Bureau will examine the information for milestone compliance and make an entry into the Master Register.

Should an NGSO system fail to meet any of the milestone requirements, the Radiocommunication Bureau will apply a "deployment factor" to reduce the size of the constellation in the Master Register based on the milestone and the number of satellites deployed. For example, if the administration fails to meet the first milestone (10%), the constellation will be scaled to a number not greater than ten times the number of satellites then deployed. At the second milestone (50%), the system would be scaled to two times the number of satellites deployed. And for the final milestone, the constellation will be recorded at the current number of satellites deployed.

These provisions, as well as special provisions for certain transitional cases, will be reviewed at the next WRC in 2023. Several open questions remain to be resolved, including the oversight of these constellations following the conclusion of the procedure; how the deployment information will be assessed; deciding the tolerances for certain orbital characteristics; and how these systems will be coordinated will make for a very intensive WRC-23 and its preparatory period, which is already well under way. WRC-23 provides an opportunity to assess the new milestone-based procedure and to take further measures to achieve its goals.

B. Streamlined Procedures for Small Satellites (with Short-Duration Missions)

WRC-19 also acted to improve the ability of small satellites operators, including nanosats and picosats, to work within the ITUs processes to obtain assured access to LEO, another decision leading to the improved sustainability of LEO. The ITU doesn't define satellites categories by size or mass, as these features are not part of the regulatory data that is provided to the Radiocommunication Bureau by notifying administrations. The data element that does distinguish them is the length of their mission, so small satellites are denoted as satellites having short-duration missions, which is defined as not exceeding three years. These small satellite operators include non-commercial entities and by governments of newly space-faring nations; universities or high schools, or other research institutions. Their purposes extend to a diversity of services, including remote sensing, space weather research, upper atmosphere research, astronomy, communications, technology demonstration, and education.

The ITU's procedures for managing the spectrum and orbital resources pertain to all satellites, be they large or small. But these procedures, with their seven-year timeframe, do not lend themselves well to short duration mission satellites which, by their very nature, have missions – and operational lifetimes -- far shorter than the ITU's procedural timeline. Thus, these satellites are often deployed outside the ITU's processes creating risk of harmful interference to other satellites and systems.

In 2015, a group of nations from the Southern Africa Development Community (SADC), with South Africa leading the effort, proposed that the agenda for the following WRC include consideration of modifications to the existing regulatory procedures for notifying satellite networks to facilitate the deployment and operation of nanosatellites and picosatellites, taking into account their short development time, short mission time, and unique orbital characteristics [33]. Although this sensible proposal was not successful in that it did not make it on to the recommended agenda for WRC-19, the Conference did promise to consider the issue under its standing agenda item on improvement of the satellite procedures. Indeed, the Southern Africans did ultimately meet with success in 2019 as they had driven consideration of this topic during the four years of preparations within the ITU Radiocommunications Sector for WRC-19 and obtained the support, or at least sympathetic understanding, from other nations.

As is often the case at the ITU, where the steady cadence of treaty conferences, supplemented by ongoing deliberations in regular technical preparatory meetings, enables serial consideration of emerging complex issues, often resulting in adoption of incremental measures that can be tried and tested and then improved upon at a future conference. Thus, the ITU's decisions are often evolutionary, rather than revolutionary, but they serve to enable the implementation of innovations in technologies and services, as is true to the Union's very purpose. In the case of small satellites with short-duration missions, WRC-19 adopted a Resolution providing some relief in addition to tweaks to the Radio Regulations to tighten the procedural timeline applicable to everyone, and to modify the required data elements to accommodate small satellite operations.

Resolution 32, "Regulatory procedures for frequency assignments to non-geostationary-satellite networks or systems identified as short-duration mission not subject to the application of Section II of Article 9 (Sharm el-Sheikh, 2019), applies to small satellite networks, or systems not exceeding ten satellites, whose mission does not exceed three years, without the possibility for extension, and do not operate in the services or allocations of the major commercial communications satellites. The Resolution takes several important small steps to tailor the application and timing of the regulations for the benefit of these satellite operators. It establishes date of the launch of the first satellite as the date of being brought into use. It provides instructions to the Radiocommunication Bureau to take measures to expedite the processing of short-duration mission satellites, to post information as received on the ITU's website, and compressing certain procedural steps, and waiving others. Administrations are also encouraged to make every effort to accelerate their analysis of small satellite filings and to quickly resolve interference concerns. As is the case for all satellites, the Resolution reiterates that small satellites with short-duration missions must have the capability of ceasing transmissions immediately in order to eliminate harmful interference. The Director is instructed to report to WRC-23 on the implementation of the Resolution. WRC-19 also modified the Radio Regulations to shorten initial steps in the coordination process from nine months to six. Administrations were not willing to shorten their response time, although a footnote was added to the provision [No. 9.3.1] to encourage them to respond as soon as possible. Finally, the required data elements for satellite filings were modified to accommodate short-duration satellites [27].

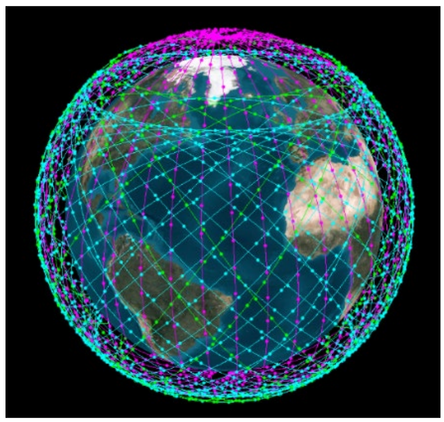

Fig. 3: An illustration of one of the proposed V-Band NGSO systems in LEO in 2016.

C. New Approach to Managing GSO & NGSO in the V-Band

WRC-19 made bold, decisive decisions to enable the next generation of LEO NGSO systems to operate in the V-band, the next global communications satellite allocation available to support the growth of next-generation commercial satellite services following saturation of the Ka-Band for GSO networks and the Ku/Ka-Band allocation that is prioritized for NGSO systems. Specifically, at issue were the frequency bands 37.5-39.5 GHz, 39.5-42.5 GHz, 47.2-50.2 GHz and 50.4-51.4 GHz.

In the Radio Regulations, allocations to the Fixed-Satellite Service (FSS), which supports most commercial communications satellites, including the megaconstellations, generally allow either GSO or NGSO operations, absent a specification otherwise. However, Article 22 provides regulatory priority to GSO networks in these frequency bands. It mandates in No. 22.2 that NGSO systems shall not claim protection from GSO networks in the FSS and enumerates technical sharing provisions on how NGSO operations are to control their interference into GSO networks [25]. However, the Article 22's detailed technical provisions only address operations below 30 GHz as they were adopted at WRCs in 1997 and 2000 based upon the proposed systems and technology of that era, such as the Teledesic system [34]. That approach set a strict emission limit, an equivalent power flux density (EPFD), to limit NGSO systems to ensure protection of GSO networks. As a result of a late-conference political compromise, the limit was calculated based on the expected emissions of 3.5 homogeneous NGSO systems – based on 20th century technology. The Conferences also took action to exempt a portion of FSS spectrum in Ku and Ka-Bands from application of Article 22 in order to prioritize it for development of NGSO-FSS systems. Although, none of those proposed systems ever materialized, today's emerging megaconstellations, including OneWeb, Starlink, and the proposed Amazon Kuiper system, directly benefit from these regulations made at the end of the last century.

As technology has continued to develop, such as phased array antennas, beam forming techniques, and digital processing capabilities, it is becoming both technically and commercially feasible to utilize higher band, or millimeter band spectrum, to provide satellite services. The physical properties of this spectrum range, though challenging, provide the potential of providing high-speed, high capacity broadband services. Also appealing is the fact that this large spectral region is largely undeveloped, a veritable spectrum green field, although for these very same reasons, it was also targeted for use by terrestrial 5G services. The physical challenges of higher band spectrum, including greater attenuation from the atmosphere such as rain fade also have the beneficial impact of lessening the interference impact on other systems. Thus, a strict application of the 1990s-era regulations to satellite operations in this higher frequency range would result in inefficient use of the spectrum and would unnecessarily constrain the number of systems and services that could be offered to all the world's inhabitants. WRC-19 included an agenda item dedicated to exploring new sharing approaches that would encourage innovative GSO and NGSO satellites to be implemented utilizing the V-Band and a needed update to the Radio Regulations [35].

Albeit one of the most complex and contentious items of the conference, WRC-19 decided to adopt an entirely new sharing approach for satellite sharing in V-Band that will allow for flexibility in system design for new NGSO systems. Instead of setting a fixed limit on the number of NGSO systems based on an outdated model, the new metrics will protect GSO networks based on the aggregate emissions of the actual NGSO systems that are deployed. WRC-19 adopted new provisions for Article 22 based on a single-entry and aggregate short term and long term protection metric. These metrics will be based on actual systems and will be periodically reviewed by a consultation group that will track the aggregate contribution of operational NGSO systems. These new regulatory provisions are supplemented by new Resolutions, including Resolution 769, "Protection of geostationary fixed-satellite service, broadcasting-satellite service, and mobile-satellite service networks from the aggregate interference produced by multiple non-GSO FSS systems in the frequency bands 37.5-39.5 GHz, 39.5-42.5 GHz, 47.2-50.2 GHz and 50.4-51.4 GHz" (Sharm el-Sheikh, 2019) [27]. Additional details on this new approach, including on the coordination of NGSO systems will need to be further considered by WRC-23. It is also expected that future conferences may wish to utilize this sharing approach for Ku and Ka-Band systems in order to attain further efficiencies in spectrum and orbital use.

5. CONCLUSION

The ITU, through its quadrennial World Radiocommunication Conferences, is a reliable and effective inter-governmental institution that, in partnership with private sector technology leaders, is facilitating innovation and the introduction of new space systems and space-based services to serve the planet, while making extensive efforts to balance these new systems with the need for sustainability of the spectrum and orbital resources that it manages for the benefit of mankind. The ITU creates relevant space law multiple times each decade as technology advances and provides a proven model for future efforts to forge global consensus to promote and manage space activities for the benefit of all.

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