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22 April 2021

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(Submitted electronically to advmn@trai.gov.in)

Subject: Viasat India Private Limited Comments on Telecom Regulatory Authority of India (TRAI) Consultation Paper No. 1/2021: "Licensing Framework for satellite-based connectivity for low bit rate applications"

Introduction

Viasat India Private Ltd. (Viasat India) appreciates the opportunity to respond to the Telecommunications Regulatory Authority of India (TRAI)'s consultation paper No. 1/2021: "Licensing Framework for Satellite-Based Connectivity for Low Bit Rate Applications" (consultation). The consultation raises important and timely questions for identifying the opportunity that satellite broadband connectivity can bring for the Internet of Things (IoT) and other services. Opening the market for satellite connectivity services, including IoT, will unlock huge potential in the Indian economy. Viasat India's remarks below follow our previous responses to TRAI's consultation on the "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed" in September and November 2020[1].

Viasat India is part of a family of companies that are leading global providers of satellite and terrestrial broadband communications solutions and that operate a large fleet of Ka-band spacecraft. Viasat has been in operation for more than 30 years and has more than 5,200 employees across 30 offices around the world, including hundreds of employees in Chennai, India.

Today, India simply does not have sufficient satellite capacity to meet the broadband connectivity needs of government, its citizens and industry. Viasat is preparing to serve the Indian market and believes that liberalization in market access will create opportunities to connect hundreds of millions of Indians to affordable high-speed broadband, as well as to jump start the IoT industry

[1] *See* TRAI consultation 6/2020, *Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed* (2020), https://trai.gov.in/consultation-paper-roadmap-promote-broadband-connectivity-and-enhanced-broadband-speed.

to facilitate smart agriculture, smart manufacturing, and smart cities. Each of these verticals will in turn create jobs, investment, and new entities to help meet India's broadband connectivity requirements.

Today, Viasat broadband services connect 150 million devices per year on airplanes and provide millions of connections to residential and enterprise customers, through a fleet of geostationary (GSO) satellites. Viasat has three additional Ka band spacecraft, ViaSat-3 class satellites, under construction and slated for launch to serve the Americas, EMEA and Asia-Pacific, including India, and has invested billions in broadband globally. Viasat also is developing plans for a fleet of non-geostationary (NGSO) satellites that can augment the more cost-effective and greater volumes of bandwidth offered by GSO. Viasat believes in fearless innovation and is finding better ways to deliver connections with the capacity to change the world. Viasat is developing the ultimate global communications network to power high-quality, secure, affordable, fast connections to improve people's lives anywhere they are—ubiquitously on land for fixed and mobile applications, gate-to-gate for aviation and pier-to-pier for maritime users.

Satellite must be part of India's broadband connectivity solution. The ongoing revolution in satellite broadband technology and associated economic models create opportunities to improve the lives of many millions of Indian citizens and unlock huge potential in the Indian economy, by making sure that broadband is accessible, affordable, and readily available anywhere in the country: in urban, suburban, and rural areas, alike. Based on analysis done by the International Telecommunication Union (ITU), a 10% improvement in fixed broadband penetration leads to a 1.38% improvement in GDP for many countries[2]. Research by global consultancy Deloitte shows that India's broadband penetration stands at just over 50%, while in rural areas, it is just below 30%[3]. This means that the total economic opportunity of bridging the digital divide in India is a 6.9% increase in GDP, translating to nearly 14.5 trillion (14.5 lakh crore) Indian Rupees. This economic growth for India would generate millions of jobs, improve educational opportunities, and help advance the country's national policy objectives including the Atmanirbhar Bharat policy.

Viasat read with great interest the consultation and provides answers to specific questions below. In addition, we have several observations that we wish to highlight here:

- In Section 1.5, TRAI raises interesting and good applications for IoT, but it's worth highlighting that satellite networks can also provide high-bit-rate applications on the same network. This will allow India to reap the benefits of high-speed broadband for residential, enterprise, government, mobile operator network, and aeronautical, land, and maritime mobility uses, while also serving the lower-bit-rate applications for IoT.

[2] *See* https://www.itu.int/en/ITU-D/LDCs/Documents/2019/Economic-impact-of-broadband-in-LDCs,-LLDCs-and-SIDS.pdf at page vi.

[3] *See* https://www2.deloitte.com/content/dam/Deloitte/in/Documents/technology-media-telecommunications/in-ra-cii-broadband-report-telecom-convergence-summit.pdf.

While some IoT specific networks are under development, more flexible broadband networks will be able to leverage the economics of broadband satellite to more affordably connect both IoT and end user services to the data they need. This is similar to fiber and other terrestrial networks – a fiber network dedicated to low-bit-rate activities would scarcely make sense, as the operator would seek to utilize the network to the best economic and technical advantage. For example, the ViaSat-3 class satellites under construction today will allow 100 Mbit/s services to end users but can also be used to provide connectivity to a smart agriculture mesh network, for example. The next-generation ViaSat-4 satellites under development offer even more advantages. This flexibility provides greater market certainty to satellite network operators, improves options for consumers, and ensures greater benefit to the Indian market.

In this regard, Viasat's Ultra-High-Throughput-Satellites (UHTS) have a significant technological and economic advantage. In addition, there are significant advantages provided by Viasat's broadband solutions stemming from our vertical integration. Rather than use a variety of components and products from other manufacturers, we typically use parts and systems that we design to ensure the best performance possible. Our innovative ecosystem of ultra-high-capacity Ka-band satellites, ground infrastructure and user terminals provide an end-to-end platform that creates significant synergies for the benefit of the end user in the form of cost-effective, high-speed, high-quality broadband solutions and applications for enterprises, consumers, military and government users alike. As displayed in Figure 1 below, investment house Morgan Stanley confirms that Viasat's geostationary satellites will remain the most cost-effective way of providing satellite broadband connectivity worldwide and depicts the advances Viasat has made in just a few years as we evolved from our prior-generation ViaSat-2 design to the ViaSat-3 satellites now being built for the Americas, EMEA, and APAC.

Cost effectiveness of next-generation UHTS Satellites (Lower is better)
(Cost per Gbit/s-months)

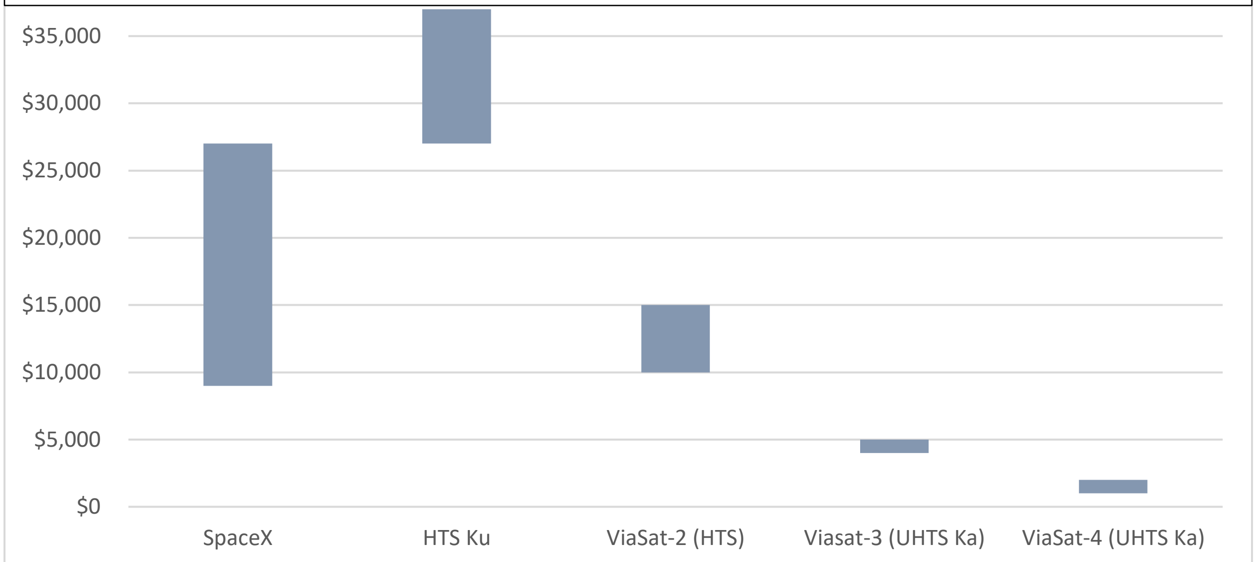

Figure 1- Next Generation Ultra-High-Throughput-Satellites (UHTS) will change the economics of satellite broadband. (Source: Morgan Stanley, July 20, 2020; Source: Company Data; Note: LEO utilization assumed at 5-15% with 5 year useful life vs GEO at 75-100% with 15 year useful life; Costs do not include user terminals; SpaceX based on initial constellation of ~12k satellites costing ~$20B; ViaSat-4 annotation provided by Viasat).

Viasat has established itself as the global leader in provision of affordable satellite capacity and has led the industry in a revolution in UHTS technology. We have changed the economics and quality of satellite broadband by increasing total capacity by a factor of 500x while reducing the cost per bit by a factor of 400x. This allows us to deliver high quality and affordable broadband connectivity no matter where people live, work or travel. Notably, ViaSat-3 provides the lowest cost per Gbit/s of any system under development today, including advanced Low-Earth Orbit (LEO) systems, which translates into a wider range of affordable connectivity options that we are able to offer. ViaSat-4 will provide even more compelling economics.

- Section 1.8 raises captive networks for private enterprise. This is particularly salient to the transportation industry, which has been hit hard by the COVID-19 pandemic. In order to recover their operations, airlines, railways, bus lines and shipping lines will seek to leverage connectivity (for example, onboard connectivity for passengers or for improved business operational efficiencies) and to drive the digital transformation of their businesses. Here, IoT has an important role – aircraft maintenance will increasingly rely on a network of sensors that relay information in real time to an airline's operation center, to help make predictive decisions about taking aircraft offline for maintenance and help monitor fuel consumption. Additionally, providing connectivity for cockpit communications and the Electronic Flight Bag (EFB) yields improvements in safety, operational efficiency, and enables real-time updates between the flight crew and the airline operations center.

- Additionally, Section 2.18 makes assumptions about the size and weight of LEOs that might not encompass the full range of satellites being constructed today. For example, Viasat's "Link 16" satellites are LEO cubesats that weigh roughly 23 kg, while other LEO network satellites are estimated to weigh between 230 and 600 kg. TRAI is correct to note that LEO networks generally cost more to operate than GEO/MEO networks, owing to the higher number of satellites, higher replacement frequency, and the fact that LEO satellites spend most of their time over unpopulated areas and thus are very inefficient. This is reflected in Figure 1 above, which shows that GEO networks will continue to be the most cost-effective method for connecting the unconnected and building IoT connectivity as well.

- Finally, we present as a response to Question 14 and in the Annex to this response, growing concerns with the proliferation of many thousands of satellites being launched into LEO orbit as part of mega-constellations and the harms related to such constellations including: (i) constraining India's access to shared and limited orbits and spectrum in the region of space near Earth, including for national satellite programs in telecommunications, earth observation and other scientific endeavors, (ii) limiting consumer choice and competition, (iii) impairing access to the dark and quiet sky that is vital to scientific research, and (iv) polluting the environment.

In the responses below, Viasat provides its answers to the questions posed by the consultation document.

Q1. There are two models of provision of satellite-based connectivity for IoT and low-bit-rate applications— (i) Hybrid model consisting of LPWAN and Satellite and (ii) Direct to satellite connectivity.

(i) Whether both the models should be permitted to provide satellite-based connectivity for IoT devices and low-bit-rate applications? Please justify your answer.

Viasat Response: Viasat recommends that TRAI permit both models for IoT satellite-based connectivity to IoT devices and low-bit-rate applications. Different IoT devices and configurations have different connectivity requirements, and both models are important to IoT users. For example, in a smart agriculture application, soil moisture sensors are ideal for a Low Power-Wide Area Network (LP-WAN) configuration or potentially mesh networking across a very wide area, while an automated irrigation system might require a direct to satellite link. In addition, it is important to recognize that satellite networks are designed and deployed to meet a variety of use cases and requirements, and many satellite networks are designed to carry IoT and consumer data traffic to maximize their economic efficiency. Today's UHTS advanced geostationary satellite networks are providing a variety of fixed and mobile applications in the Ka band frequencies, including the 27.5-29.5 GHz (28 GHz) band, as well as the L and S bands (1.5-2.7 GHz). Satellite operators are also developing specialized earth stations or antennas to operate in many different IoT environments, including over UHTS satellite networks.

(ii) Is there any other suitable model through which the satellite-based connectivity can be provided for IoT devices? Please explain in detail with justifications.

Viasat Response: As mentioned above, satellite networks are designed to serve a variety of use cases. The same satellite system that connects a passenger airliner gate-to-gate and provides broadband for crew and passengers, connects IoT sensors on board the aircraft, and connects residential customers and extends mobile networks. Networks need to be able to flexibly serve all verticals, finding the right mix for their business. Therefore, we recommend that TRAI focus on a wholistic regulatory regime that is less restrictive for satellite connectivity and improves the overall satellite market offerings available for Indian consumers.

Q2. Satellite-based low-bit-rate connectivity is possible using Geo Stationary, Medium and Low Earth orbit Satellites. Whether all the above or any specific type of satellite should be permitted to be used for providing satellite-based low-bit-rate connectivity? Please justify your answer.

Viasat Response: All of the above types of satellite networks should be permitted to provide satellite-based connectivity in India. As we indicated above, the economics of GSO satellite broadband are improving rapidly, led by Viasat's continued dedication to improving the cost-per-Gigabit for broadband. As outlined in Figure 1 above, GSO satellites will continue to have the most cost-efficient bandwidth in the satellite market for the foreseeable future. While certain satellite types can provide different niche service needs, all types of satellites can serve low-bit-rate services. Additionally, hybrid networks, including GSO + NGSO or GSO + terrestrial DSL or wireless configurations are important solutions to solve the digital divide. Viasat has developed hybrid technology that optimizes the service provided to the end user based on certain parameters such as total throughput need, latency sensitivity, etc., with impressive results. Such hybrid networks provide network operators with flexibility to innovate in how they serve customers, focusing on market dynamics, including cost and higher quality of service. It is also worth mentioning that the ITU World Radio Conference 2023 (WRC-23) is studying satellite-to-satellite links (Agenda Item 1.17), including NGSO-GSO links, that support real-time IoT data processing for LEO satellites that are not within the line of sight of a gateway.

Q3. There are different frequency bands in which communication satellites operate such as L-band, S-band, C-band, Ku-band, Ka-band and other higher bands. Whether any specific band or all the bands should be allowed to be used for providing satellite-based IoT connectivity? Please justify your answer.

<u>Viasat Response</u>: Yes, all satellite frequency bands should be able to provide satellite-based IoT, especially Ka-band. Viasat is working today in a variety of bands, including the L-, S-, and Ka-bands providing IoT, and the Ka-band for consumer Internet access. The Ka-band is clearly the driver of the economic improvements of satellite broadband. As outlined below in Figure 2, as the amount of satellite capacity on a given Ka-band satellite improves, the cost per Gbit/s falls in a commensurate manner. This means that as UHTS networks come online, Ka-band capacity is becoming the most cost-effective satellite solution on the market. As a result of this improvement in available capacity and cost-efficiency, many countries are making the 28 GHz band available exclusively for satellite broadband services. These countries are providing the necessary spectrum for satellite services to meet end-user demand and also allow these satellite services to evolve in the band, while accommodating terrestrial IMT/5G and other terrestrial service deployments in bands identified for those services such as the 26 GHz band.

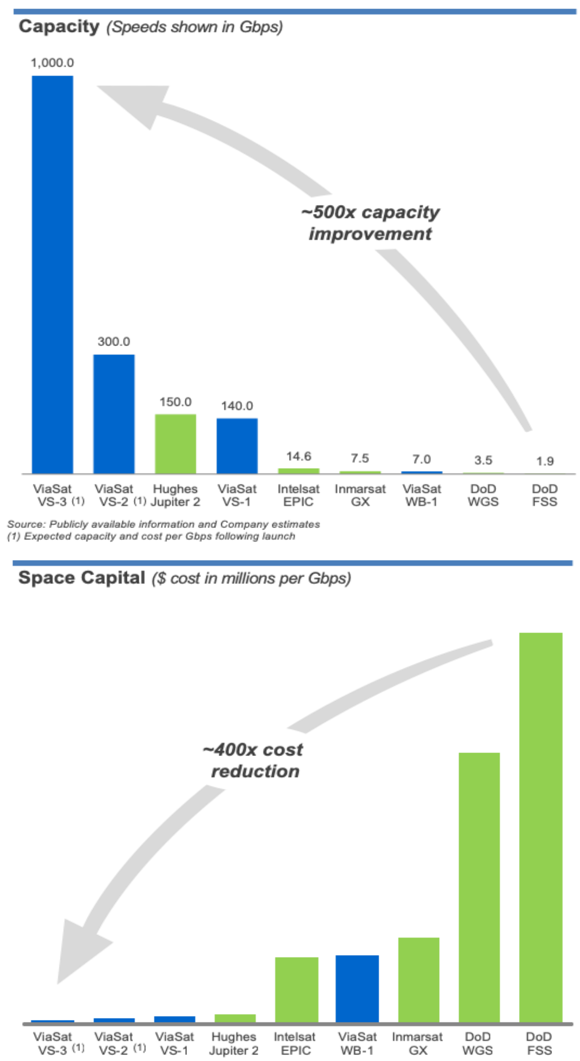

Figure 2- the improving economics of satellite broadband show a significant capacity improvement and a commensurate reduction in cost.

Notably, the 28 GHz band is poorly suited for terrestrial IMT/5G operations. One of the few countries using a portion of the 28 GHz band for both terrestrial and satellite services, the United States, had to accommodate previously licensed LMDS technology, while Ka-band satellite was in its infancy. When the LMDS failed and there were few other options at the time, the United States made the LMDS spectrum (i.e., 27.5-28.35 GHz) available for terrestrial IMT/5G, while still protecting satellite gateways access (over 9,000 gateways nationwide) in the band and left open the possibility of blanket licensing for satellite user terminals in the future. TRAI should be aware that recently the predominant terrestrial operator in the 27.5-28.35 GHz LMDS band, Verizon, was unable to make productive use of the spectrum and in March 2021 began selling off its licenses in the 28 GHz band[4].

We wish to draw TRAI's attention to the fact that companies like Viasat have made significant technological advances in addressing rain-fade through the use of Adaptive Coding and Modulation (ACM) techniques, which allow the network to improve resiliency automatically when atmospheric issues arise. This provides Ka-band UHTS satellite systems a significant advantage over older technology and is the reason Viasat is able to operate many thousands of Ka-band terminals in some of the highest rain regions on earth, for example the Amazon rainforest and the jungles of southern Mexico.

Q4. (i) Whether a new licensing framework should be proposed for the provision of Satellite-based connectivity for low-bit-rate applications or the existing licensing framework may be suitably amended to include the provisioning of such connectivity? Please justify your answer.
In case you are in favour of a new licensing framework, please suggest suitable entry fee, license fee, bank guarantee, NOCC charges, spectrum usage charges/royalty fee, etc.

Viasat Response: An IoT-only network license would likely result in duplication and confusion on the part of network operators and consumers. This would have the effect of diminishing the market, just as it is promising a new wave of investment. Most network operators, as outlined above, are traffic agnostic in the sense that they can carry a variety of traffic for different customers. For example, Viasat connects millions of users to high-speed broadband in its Community Internet program, and also is able to serve as either the primary or backup link for a variety of Machine-to-Machine (M2M) communications for the finance industry. Just as an IoT-only fiber network is unlikely to succeed, satellite networks need to be able to serve a mix of customers to justify the significant investment in a satellite network. The cost of deploying UHTS satellites (typically over INR 37 lakh rupees each) means that the network should be flexible for all services, and regulation should reflect this need. Additionally, the ability to serve multiple customers helps ensure financial resiliency in the business, which helps maintain cost-effective services for IoT.

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4 *See: Verizon sells some 5G spectrum to GeoLinks* (25 March 2021), https://www.lightreading.com/5g/verizon-sells-some-5g-spectrum-to-geolinks/d/d-id/768346.

At the more practical level, IoT and consumer broadband network deployment have similar requirements: both need a blanket license to enable rapid and ubiquitous deployment, clear and stable spectrum access to facilitate investment and service deployment, and the ability to evolve to address new use cases, including mobility use cases, such as Earth Stations in Motion (ESIM).

Instead of creating an IoT-only satellite license, Viasat respectfully recommends that India make satellite services more broadly available in India, including from all satellite broadband connectivity providers, fostering an enabling environment for satellite network operators to invest in India, and keeping entry fees in line with other comparable markets such as Brazil, the United States, and the European Union. In those areas, fees are kept low to generate investment from a wide variety of service providers rather than serve as a barrier to entry, and the focus is on the economic impact from an improved telecoms sector, thereby growing the broader economy and the tax base, rather than on fees as a revenue source for government.

Q5. The existing authorization of GMPCS service under Unified License permits the licensee for provision of voice and non-voice messages and data services. Whether the scope of GMPCS authorization may be enhanced to permit the licensees to provide satellite-based connectivity for IoT devices within the service area? Please justify your answer.

Viasat Response: Viasat does not have any comments on this question.

Q6. Commercial VSAT CUG Service authorization permits provision of data connectivity using VSAT terminals to CUG users.

(i) Whether the scope of Commercial VSAT CUG Service authorization should be enhanced to permit the use of any technology and use of any kind of ground terminals to provide the satellite-based low-bit-rate connectivity for IoT devices?

(ii) Whether the condition of CUG nature of user group should be removed to permit provision of any kind of satellite-based connectivity within service area? Please justify your answer.

Viasat Response: While some closed user groups (CUGs) are a result of a specific situation where the telecom market doesn't provide options and users are uniformly identifiable as pertaining to a group (such as in ESIM use case, where the airline, shipping line or bus line chooses the connectivity provider for the entire cabin, and consumers can't choose the provider directly), in general, a broad-based VSAT framework that enables more rapid deployment on a blanket license basis better incentivizes investment and ubiquitous deployment of satellite services.

Q7. (i) What should be the licensing framework for Captive licensee, in case an entity wishes to obtain captive license for using satellite-based low-bit-rate IoT connectivity for its own captive use?
(ii) Whether the scope of Captive VSAT CUG Service license should be modified to include the satellite-based low-bit-rate IoT connectivity for captive use?
(iii) If yes, what should be the charging mechanism for spectrum and license fee, in view of requirement of a large number of ground terminals to connect large number of captive IoT devices?

Viasat Response: Viasat does not have any comments on this question.

Q8. Whether the scope of INSAT MSS-R service authorization should be modified to provide the satellite-based connectivity for IoT devices? Please justify your answer.

Viasat Response: Viasat does not have any comments on this question.

Q9. (i) As per the scope mentioned in the Unified License for NLD service Authorization, whether NLD Service providers should be permitted to provide satellite-based connectivity for IoT devices?
(ii) What measures should be taken to facilitate such services? Please justify your answer.

Viasat Response: Viasat does not have any comments on this question.

Q10. Whether the licensees should be permitted to obtain satellite bandwidth from foreign satellites in order to provide low-bit-rate applications and IoT connectivity? Please justify your answer.

Viasat Response: Yes, licensees should be permitted to obtain satellite bandwidth from foreign satellites to provide low-bit-rate and IoT connectivity, as well as all other types of connectivity. The distinction between IoT and end-user broadband is limited and most networks are built to handle both. A national policy that allows foreign satellite operators to serve India with UHTS capacity on GSO satellites will immediately bring tens of billions of rupees of foreign investment and lead to massive improvements in the connectivity for hundreds of millions of Indians. The capacity that India truly needs to fulfill the PM-WANI scheme, for example, is in the offing with GSO satellites that are being built and will soon be deployed – the only requirement is for India to open the market to enable non-Indian satellites to meet the broadband connectivity requirements of India.

We endorse TRAI's advocacy for an Open Sky Policy and agree that it is "the only way forward" if India truly wants to bridge the digital divide[5]. An Open Sky policy should

5 *See* consultation document at page 42.

include GSOs as well as NGSOs and offer the full range of satellite services on a level playing field, creating a dynamic and robust market.

Q11. In case, the satellite transponder bandwidth has been obtained from foreign satellites, what conditions should be imposed on licensees, including regarding establishment of downlink Earth station in India? Please justify your answer.

Viasat Response: There should not be any downlink conditions such as local gateway requirements. Local gateway requirements drive up cost and complexity, and hinder investment in the sector and deployment of services. Satellite operators like Viasat are evolving beyond traditional gateways to use modern, cloud-based architectures (like many communications services) that provide greater network flexibility, capacity, and resiliency, while meeting India's national security needs. As long as the foreign satellite operator can satisfy the Indian security and other requirements through an appropriate technical means (regardless of the location of physical infrastructure), they should be granted a license to operate in India. As a result, legacy network components, like large gateways, have evolved into virtual network nodes that provide the same, or better, service for national security purposes, while creating a more flexible network and reducing operating costs. This approach generates more affordable broadband access for users.

Q12. The cost of satellite-based services is on the higher side in the country due to which it has not been widely adopted by end users. What measures can be taken to make the satellite-based services affordable in India? Please elaborate your answer with justification.

Viasat Response: Today's UHTS networks are dramatically lowering the cost-per-bit, as demonstrated in Figure 2 above. These improvements are passed on to end users in terms of capacity increases and lower costs-per-gigabit. As outlined in the above section on the economics of satellite broadband, the costs of satellite connectivity are becoming more affordable around the world. Viasat is leading this rapid evolution in satellite technology which can bring 4G and 5G speeds to India and provide far more advanced services than ever before possible by satellite. A flexible and open Indian regulatory regime would allow operators like Viasat to bring satellite services that will provide these benefits.

Likewise, fees for licensing and spectrum use should be kept to the minimum to attract investment in the broadband sector. Noting that terrestrial operators in India have struggled with low average revenue per user (ARPU), even in wealthy parts of India, it is logical that keeping fees down will facilitate investment by satellite operators for low-cost, high-throughput solutions for both IoT and consumer services. Given that much of the terrestrial mobile operators' networks do not currently extend into less densely populated areas, Viasat's network-as-a-service (NAAS) solution allows it to deploy the infrastructure that extends mobile networks into communities and neighborhoods that remain unconnected. In the IoT segment, there are different use cases. For example, high-bit-rate, low-bit-rate, frequent message traffic and infrequent message traffic. This means a flexible licensing framework is important to enable the full scope of the IoT offerings. With many new use cases focusing on ultra-low-cost services, it is important to ensure licensing is simple and incentivizes growth and does not restrict or create prohibitive costs. Specifically, we recommend that India avoid a fixed-cost licensing model as that would create a prohibitively high burden for extending connectivity to the hardest to serve areas.

Q13. Whether the procedures to acquire a license for providing satellite-based services in the existing framework is convenient for the applicants? Is there any scope of simplifying the various processes? Please give details and justification.

Viasat Response: Telecommunications networks are increasingly operating on a multi-technology basis. For example, hybrid networks as described above, terrestrial and satellite networks working together to extend connectivity, ESIM antenna technologies that leverage mobile and satellite connectivity to give emergency response vehicles an always-on connection. These networks operate in urban, suburban, and rural locations. Ideally, all of these technologies would be authorized by an independent and unitary regulatory authority. This would be in-line with the vast majority of countries, where there is a centralized and independent regulatory authority to ensure proper market functionality, foreign operator entry and domestic licensing.

Regarding the licensing process itself, we respectfully suggest that global best practices favor a transparent and streamlined application process that better provides certainty to industry, facilitates investment, and brings a wider range of solutions. These features will improve accessibility and affordability of broadband and low-bit-rate services for India. The licensing process should be streamlined to include the points discussed below.

- Permitting the operation of foreign satellite networks, including GSO systems.
- Granting landing rights to foreign networks that have a local presence and that agree to abide by Indian law and regulations.
  - Coordination with other GSO satellite networks should be required only when necessary, and a database of authorized satellite systems should be publicly available including the systems that are licensed, deployed and operational in India. This would help applicants understand any necessary coordination requirements before soliciting market access.
- Conditions on NGSO systems regarding how they use scarce orbital and spectrum resources, in order to promote a competitive marketplace. In addition, NGSO networks should be reviewed for environmental implications and the impact on astronomy, earth observation, and other sciences. We have outlined these considerations in detail in Annex I of this document.
- Blanket licensing for ubiquitous user terminal deployment, using a blanket license fee rather than per-terminal fee. Annual reporting should be done in relation to this,

always on an *ex post facto* basis and including only information that is of importance to the TRAI's function of regulating the competitive and technical landscape.

- Allowing foreign GSO ESIM to operate in India for periods of up to 4 weeks without registration requirements, so long as they are duly authorized by the country where they are flagged. At the 4-week period, local registration may be required. Given that most foreign airlines' aircraft are in India for only a couple of hours, this would streamline the majority of foreign ESIM while still providing for control over any long-term operations in the country.
- Authorizing ESIM (both foreign and domestic) operations, in line with global trends and the ITU WRC-19 outcomes. We recommend making the Ka-band, including the 17.7-19.7 GHz and 27.5-29.5 GHz bands, available for satellite broadband connectivity. The ITU has provided rules for the rare instance of cross-border, co-frequency ESIM operation with licensed and operating terrestrial services. Outside of those rare occasions:
  - Ka-band GSO aeronautical ESIM should be authorized to operate gate-to-gate, including ground operations;
  - Maritime ESIM should be authorized to operate pier-to-pier;
  - Land ESIM should be authorized to operate ubiquitously.

Q14. If there are any other issues/suggestions relevant to the subject, stakeholders are invited to submit the same with proper explanation and justification.

Viasat Response: Very large NGSO constellations can have significant and adverse environmental, competitive and technological effects and implications that we respectfully recommend India begin considering now. As mentioned above, we have provided an analysis of the serious issues related to LEO mega-constellations that we urge India to consider. This is a further development of the ideas we presented to TRAI in our counter comments to the consultation paper on the "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed" and is presented in the enclosed Annex I.

Again, we thank TRAI for the opportunity to participate in this public consultation and look forward to discussing these issues with you further.

Respectfully submitted,

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ANNEX I: Regulation of NGSO Systems

Recently, low earth orbit (LEO) has become more readily accessible, and new low-cost launch options are becoming available from multiple sources. LEO constellations can augment other national telecommunications network resources such as GSO satellites, wireless networks, data centers, and cloud centers. Previously, the rules to manage the risks were adequate. That is no longer the case. Today, self-interest and the public good are quickly diverging, as the cost of failure to an individual actor is far, far less than the collective risk of that failure.

In fact, leading international organizations call these mega-constellations "game changers" that can create a new "ecological tipping point" when it comes to space junk and pollution. As a result, they have released calls for action that include addressing these threats at the national level. Indeed, as a just-released book explains, the launch of such a "mega-constellation" from one jurisdiction has profound impacts on many other jurisdictions around the world.

> "The new sky pollution - swarms of satellites - is even more global. When you a launch a satellite in Low Earth Orbit, within an hour and a half it has circled the globe. You may launch from Florida or Kazakhstan, but you are instantly polluting Namibia and France." [6]

Viasat respectfully recommends that India address these issues when considering market access requests for LEO mega-constellations, and before granting its share of limited orbital resources to individual foreign companies. In particular, India should consider, before granting market access, how a LEO mega-constellation can (i) constrain India's access to shared and limited orbits and spectrum, including for national satellite programs in telecommunications, earth observation and other scientific endeavors, (ii) limit consumer choice and competition in India, and (iii) disrupt a dark and quiet sky and impair important scientific research, and (iv) pollute the environment.

1. <u>Constraining NGSO Interference into GSO networks</u>.

Under Number 22.2 of the International Telecommunication Union (ITU) Radio Regulations, systems of NGSO satellites (including those in LEO) "shall not cause unacceptable interference to … geostationary networks in the fixed satellite service." India can create new high technology jobs and participate in global efforts around LEO satellite system design, manufacture, operation, and network planning. At the same time, India can maintain national sovereignty over the use of space to serve its territories.

Even a single LEO mega-constellation has the potential to cause harmful interference into multiple GSO networks, resulting in significant degradation and capacity losses for GSO networks

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1 *Losing the Sky - The threat from satellite mega-constellations, why it matters, and what we can do about it*, Andy Lawrence with assistance from Jonathan McDowell, Robert J. Antonucci, Photon Productions, (February 8, 2021), at page 5.

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that would serve India. Multiple NGSO systems operating simultaneously pose an even greater risk to those GSO networks. This can impair the provision of critical GSO-based services across India from ISRO, including the INSAT program.

Today's ultra-high throughput GSO satellites are extremely efficient in how they use spectrum at the GSO arc, employing low total satellite receiver noise temperatures and high satellite receive antenna gains, to provide innovative services with smaller user terminals than ever possible before. Ensuring that those capabilities are unaffected by LEO mega-constellations, as the ITU mandates, requires mega-constellations to limit the amount of unwanted energy they emit in the direction of those GSO networks, in the form of main beams and sidelobes from their satellites and their earth stations.

One way to ensure compatibility with GSO networks (as the ITU requires) is for LEO mega-constellations to maintain a suitable level of angular separation from the GSO arc, with the requisite angle depending on the particular attributes of that mega-constellation. Certain LEO mega-constellation operators have not committed to do so across all of the frequency bands they intend to use. Notably, maintaining adequate angular separation imposes virtually no constraint on LEO system capacity.

Moreover, serious questions remain about precisely how certain LEO mega-constellations will operate, which directly affects the required level of angular separation. That is, one mega-constellation operator appears to be relying on multiple ITU filings for the same NGSO system, so that it can impermissibly aggregate multiple so-called "single entry" EPFD limits and thereby generate more interference toward GSO networks than otherwise permitted. In addition, it has not been explained why, when a LEO mega-constellation is designed to have many dozens of its satellites in sight of a given location on Earth at any given time, only one single co-frequency satellite will illuminate that location, and only that single illumination will contribute to interference into GSO networks at that location. Nor has anyone explained how a LEO mega-constellation operator will be able to both calculate and actually manage the aggregate interference impact of the many millions of sidelobes created by millions of user terminals and dozens of beams on its many thousands of satellites. Furthermore, the aggregate impact on GSO networks from the operation of multiple NGSO systems would have to be limited and apportioned among these multiple systems in both the uplink and downlink directions.

Finally, some NGSO operators are actively trying to weaken, in the ITU study process, the existing ITU rules that define certain protections they must provide GSO networks. And this does not even consider that the existing rules were not developed to address the new LEO mega-constellations or their impact on today's GSO networks.

Viasat urges India to ensure that LEO mega-constellations maintain adequate angular separation from the GSO arc and also demonstrate precisely how they will operate to avoid creating unacceptable interference into GSO networks through illumination of a single location with multiple beams and sidelobes from multiple NGSO satellites and/or earth stations.

2. Facilitating Equitable NGSO-NGSO Spectrum and Orbital Sharing

Another concern is how unconstrained LEO mega-constellations can consume significant portions of the look angles toward space, and essential LEO orbits, preventing use of the sharing tools that have been employed successfully for decades among NGSO systems.

This threat to NGSO spectrum sharing arises because mega-constellations will "blanket the sky," causing many in-line interference events limiting and sometimes completely blocking other NGSO systems from sharing the same spectrum. LEO mega-constellations will rarely experience this problem themselves because their far greater number of satellites that block spectrum use by smaller NGSO constellations provides them with alternative communications paths where the same spectrum remains available to the mega-constellation.

The spectrum-preclusive effect of these LEO mega-constellations is depicted in the following table, which shows the probability of satellites in NGSO System B blocking all of the satellites in NGSO System A. Three constellation sizes are considered for each system: 300, 3,000, and 30,000 satellites. Typical orbital parameters were used, and the user terminal was modelled at a representative location of 20.6° N, 79° E (the geographic center of India), for TRAI's reference, for the purposes of this submission. Several observations can be made:

- A 30,000 satellite NGSO system will blanket the sky, blocking all other constellations, including other similarly sized constellations from serving India.
- Even 3,000-satellite NGSO systems have a significant blocking effect on many other constellations cutting approximately 1/3 the capacity of a 300-satellite (and even another 3,000-satellite) system serving India.
- Conversely, 300-satellite NGSO systems never block 3,000 or 30,000-satellite NGSO systems.

	NGSO System B		
NGSO System A	300 Satellites	3,000 Satellites	30,000 Satellites
300 Satellites	2.9%	31.3%	100%
3,000 Satellites	0%	21.8%	100%
30,000 Satellites	0%	0%	100%

Probability that NGSO System B blocks a location from service by NGSO System A

This dynamic has the perverse effect of incentivizing a race in which LEO mega-constellations deploy many more satellites than actually needed, utilizing large numbers of spectrally-inefficient satellites and rejecting reasonable approaches that otherwise would enable spectrum sharing among all NGSO system types – even those operating at other altitudes. This would distort markets and leave only one or two LEOs with the ability to serve India, foreclosing competition. The threat to orbital sharing exists because LEO orbits are limited, and as leading experts recognize[7] LEO mega-constellation operators are in a race to populate a wide swath of the "best" orbits (in the 300 km to 650 km range) with huge numbers of satellites. And they are doing so by planning to operate with unnecessarily wide orbital tolerances, and thus would effectively fill up hundreds of kilometers of orbits to the exclusion of other NGSO systems who otherwise could operate alongside them. Particularly when LEO mega-constellations already must operate with much greater precision to avoid collisions, there is no good reason to allow mega-constellations to provide service utilizing overlapping shells of satellites in very wide orbits that unduly consume what otherwise would be shared.

Viasat urges India to work with like-minded countries around the world to develop a mechanism to allocate LEO satellite counts, orbital trajectories and spectrum fairly among all global nations. Viasat also urges India, in granting market access, to ensure equitable access to the same spectrum by multiple NGSOs, and also ensure equitable access to shared and limited NGSO orbits. Among other things, LEO mega-constellation operators should be required to operate their satellites with suitable orbital tolerances to enable others to share the same orbits.

To facilitate avoiding interference with both NGSOs and GSOs, LEO mega-constellation operators should be required to provide sufficient technical details to enable an assessment of how all other satellite systems can share the same spectrum, including:

1. Earth station and satellite transmit power density;
2. Minimum angle of separation from the GSO arc;
3. Off-axis gain and EIRP density mask for earth stations (gateways and user terminals) and satellite antennas;
4. Identification of whether the earth stations are user terminals or gateways and how many of each class will be deployed within India;
5. Number of satellites, orbits employed, orbital tolerance and other orbital characteristics;
6. Number of total beams and number of co-frequency reuses on each satellite; number and size of channels on each beam; and
7. Number of co-frequency satellites serving a location on the Earth in the uplink direction and in the downlink direction.

3. <u>Avoiding LEO Mega-Constellations Polluting Space</u>

LEO orbits have become increasing littered with space junk: "The most crowded section is between 500 and 1000 km up. It's the densest region […] of space."[8] The launch of thousands, or tens to hundreds of thousands, of mega-constellation satellites into LEO increases the risk of collisions in these crowded orbits. As the Organization for Economic Cooperation and

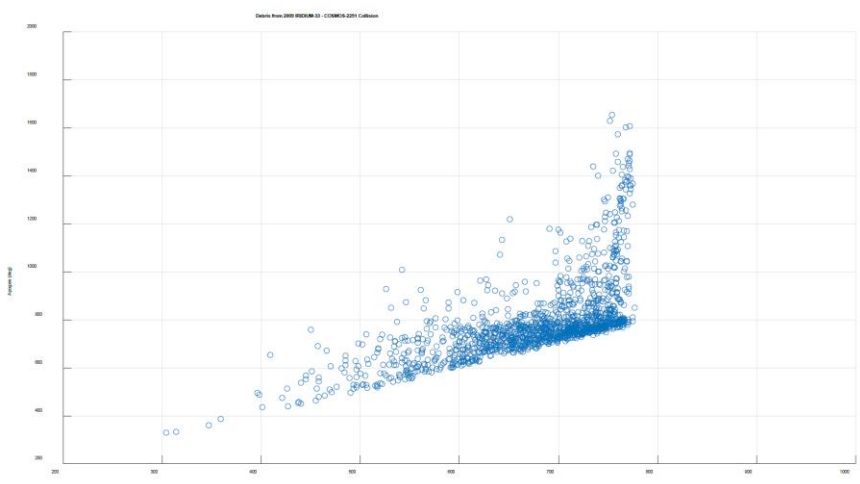
[7] *See* https://www.theverge.com/2021/1/27/22251127/elon-musk-bezos-amazon-billionaires-satellites-space.

[8] Kessler Syndrome: *What Happens When Satellites Collide,* https://asherkaye.medium.com/kessler-syndrome-what-happens-when-satellites-collide-1b571ca3c47e.

Development (OECD) recognizes[9], suitable measures must be put in place now, before it is too late, to prevent a so-called "tragedy of the commons."

The rush to fill space with expendable satellites made with off-the-shelf parts creates situations where far too many of the satellites in these mega-constellations are failing before their planned end of life, and before they safely can be deorbited. When they fail and lose maneuverability, these satellites cannot avoid collisions with other satellites or with space junk. And when they do collide, the resulting fragmentation can send clouds of shrapnel-like space junk hundreds of kilometers in each direction. This space junk can disable or destroy other satellites that are critical for connectivity, mapping, weather and defense purposes – and this space junk can persist for decades and even a century or more, making access to space riskier and more expensive for others.

A well-known example of a collision in LEO that was not avoided occurred in 2009 between an active Iridium satellite and a defunct Russian COSMOS satellite, which created 2,294 new trackable pieces of space junk, 1,396 of which still remain in orbit 12 years later. Again, the unprecedented increase in the number of mega-constellation satellites in LEO dramatically increases the probability of these types of collisions.



Spread of Space Junk from Iridium-33/Cosmos-2251 Collision

As reflected in data released by the European Space Agency (ESA), space junk produced by one collision continues to collide with itself, generating even more space junk, and further increasing the likelihood of collisions in an ever-evolving orbital environment. The following figure from the ESA depicts the growing amount of space objects in LEO, even before the introduction of mega-

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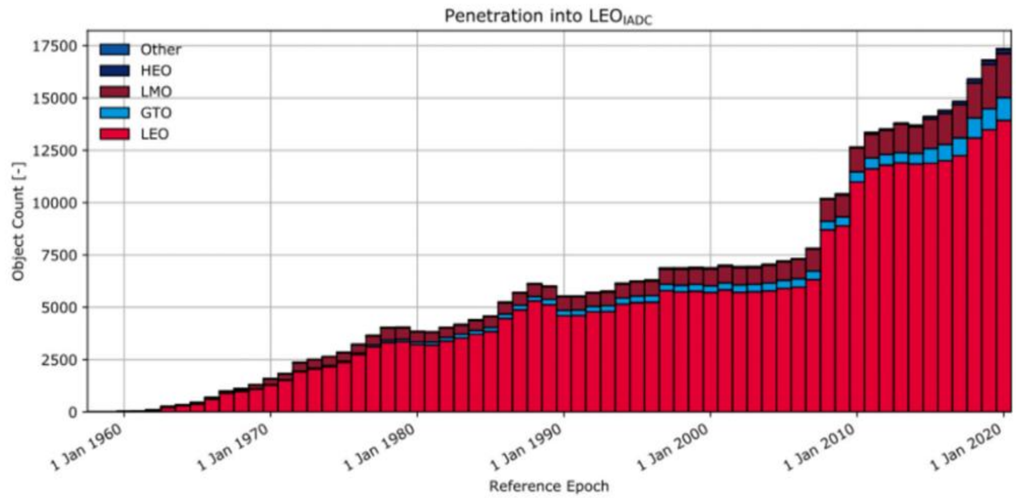
9 Organisation for Economic Co-operation and Development (OECD*), Space Sustainability: The Economics of Space Debris in Perspective,* OECD Science, Technology and Industry Policy Papers, no. 87 (April 2020): 7, 18, 26. https://read.oecd-ilibrary.org/science-and-technology/space-sustainability_a339de43-en#page1.

constellations.[10] A significant portion of recent increases is attributable to LEO satellites themselves, as well as the fragmentation of those satellites after collisions.[11]



The risks associated with two LEO mega-constellation satellites (or a mega-constellation satellite and a large piece of space junk) crossing each other's orbital planes is particularly significant because of:

- The large amount of energy that would be released when objects collide at thousands of kilometers per second at the intersection of their orbital paths;[12]
- How a significant fraction of the resulting space junk would periodically cross the orbital planes of the mega-constellation involved in the collision; and
- How the resulting space junk would spread to other orbit altitudes (as shown in the example above).

Viasat respectfully recommends that India, when considering a grant of market access for LEO mega-constellations, consider the aggregate collision risk over the entire license term, considering all of the many thousands of satellites and their replacements that could be deployed in a mega-constellation over that term. It is also essential to examine:

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10 European Space Agency Space Debris Office, *ESA's Annual Space Environment Report* (2020): 16.

11 Ibid 13.

12 R. Thompson, *A Space Debris Primer,* Crosslink (Fall 2015), at 5 ("Most conjunctions converge at about a 45-degree angle, which results in a relative velocity of approximately 10 kilometers per second—ten times faster than a rifle bullet. At such velocities, the danger to satellites and space-based systems becomes obvious. The kinetic energy of even a small particle at these speeds can do tremendous damage.").

- The risks during the entire period each satellite in a LEO mega-constellation remains in orbit, at all of the orbits it may populate during its orbital lifetime (injection, operations, and post mission disposal);
- The increased risk of collisions due to known changes in the orbital environment (additional satellites being launched, not just the environment as it existed in the past);
- The risk of collisions with all sizes of space objects (not just those ≥ 10 cm and ≤ 1 cm);
- The continued reliability of critical command and propulsion capabilities needed to allow satellites to maneuver to try to avoid collisions as long as they remain in orbit;
- The risk of intra-system collisions within any of these LEO mega-constellations (and particularly when their satellites fail); and
- Known risks with large numbers (potentially tens of millions per year) of expected conjunctions between mega-constellations and other space objects (*e,g.*, large numbers of maneuvers to avoid some collisions creates other collision risks; low probability conjunctions not avoided add up to much larger collision risks with very large numbers of conjunctions).

If LEO mega-constellations are allowed to continue to deploy without a full and complete analysis of these issues, and the adoption of suitable mitigation measures, competition and innovation in space may come to a standstill. The OECD calls the deployment of LEO mega-constellations a "game changer" and warns of the prospect for a never-ending spiral of collisions that eventually renders LEO unusable and possibly impenetrable — foreclosing access to and innovation in space for generations.[13]

Some LEO mega-constellation operators try to downplay these significant risks, by focusing on the risk associated with a single satellite, and not considering what can happen over the entire term of exploitation when thousands of satellites are operated at varying altitudes. That approach ignores the simple fact that collision risk scales with constellation size. In other words, it ignores the additive risk from each satellite in a LEO mega-constellation and the unlimited number of replacements that could be launched over the entire term. This approach would effectively sanction catastrophic collisions occurring very frequently, as depicted below:

[13] Organisation for Economic Co-operation and Development (OECD), *Space Sustainability: The Economics of Space Debris in Perspective*, OECD Science, Technology and Industry Policy Papers, no. 87 (April 2020): 7, 18, 26. https://read.oecd-ilibrary.org/science-and-technology/space-sustainability_a339de43-en#page1.

# of Satellites in Orbit	Allowed Mean Time Between Collisions in Years (Days)
1,000	5
5,000	1
10,000	0.5 (180 days)
50,000	0.1 (36 days)
100,000	0.05 (18 days)

Table A: Collision Risk Scales with Constellation Size[14]

Some LEO mega-constellation operators also try to downplay the risks by claiming that they will deploy autonomous collision avoidance mechanisms. But the effectiveness of those capabilities depends entirely on each of their satellites being able to reliably and effectively maneuver for as long as it remains in orbit—after injection, while at operational orbit, and during post-mission disposal. Satellites that fail or degrade such that they no longer can be reliably maneuvered cannot avoid collisions—with each other, with satellites in other systems, or with the large and growing amount of space junk. Thus, the deployment of unreliable LEO mega-constellation satellites presents undue risks to space and everyone who seeks to utilize space.

Of great concern are the cost/safety tradeoffs being made today in mega-constellation designs that value large numbers of low-cost, economically expendable satellites over constellations with fewer and more reliable satellites. Making that tradeoff reduces the likelihood of successfully maneuvering to avoid the inherent risk of collisions. It also means that even more satellites in the LEO mega-constellations need to be launched than are necessary leading to the other harms discussed below.

Considering that the ability to mitigate collision risk depends highly on how LEO mega-constellations actually are deployed and operated, Viasat respectfully urges the Indian administration, when evaluating a mega-constellation's market access application, to consider the aggregate collision risk over the entire term of the license, considering all of the many thousands of satellites and their replacements that could be deployed in a LEO mega-constellation over that term. Viasat also respectfully suggests that India conduct an evaluation of the entirety of the collision risk for the constellation as a whole, taking into account:

- Collision risk at all of the orbits a satellite may populate during its orbital lifetime;
- Collision risk due to known changes in the orbital environment;
- Collision risk with all sizes of space objects (not just those ≥ 10 cm and ≤ 1 cm);
- The reliability of critical satellite capabilities needed to avoid collisions;

[14] Note: Calculations are based on 5-year satellite design life, and an application of the one-in-1,000 collision risk standard commonly used in the past for single-satellite risk scenarios.

- The risk of intra-system collisions within a LEO mega-constellation; and
- Known risks with large numbers of expected conjunctions.

Because many of these matters can only be predicted at the application stage, and the problem often cannot be fixed once satellites are launched, Viasat also respectfully requests the Indian administration consider:

- Granting authority in stages (*i.e.*, for parts of the constellation at a time);
- Conditioning authority appropriately, including conditioning on confirmation that satellites are actually built and operating consistently with the representations in the application; and
- Promptly acting to address any material deviations that could pose an increased threat of in-orbit collisions including, but not limited to, withholding authority to serve India while the operator adequately addresses such deviations.

4. Environmental Issues

A. *Avoiding Mega-Constellations Polluting Our Air and Contributing to Climate Change*

LEO mega-constellations are designed so their defunct satellites re-enter the atmosphere and vaporize, releasing chemical compounds, including aluminum oxides. This can occur soon after a deployment failure, or after a satellite's useful life ends. Some LEO mega-constellations consist of satellites that have to be constantly replaced after short design (5-year) lives, which would result in a constant stream of satellites vaporizing in the atmosphere---potentially many thousands per year---an exponential increase over what has occurred to date.

The Aerospace Corporation (an advisor to the U.S. Space Force) reports that this massive increase in the number of satellites reentering the atmosphere and releasing chemical compounds could contribute to climate change through, among other things, radiative forcing and ozone depletion.[15] Most of the re-entering mass will vaporize into small particles consisting of what experts call a "zoo of complex chemical types."[16] The stratosphere where this pollution gathers is home to the fragile ozone layer that protects the Earth from ultra-violet (UV) radiation.

We have never before faced a situation where dozens of satellites *each day* would be vaporizing in the atmosphere and releasing harmful chemical compounds into the stratosphere.

[15] L. Organski, C. Barber, S. Barkfelt, M. Hobbs, R. Nakagawa, Dr. M. Ross, Dr. W. Ailor, *Environmental Impacts of Satellites from Launch to Deorbit and the Green New Deal for the Space Enterprise*. Aerospace Corporation (December 2020); Debra Werner, *Aerospace Corp. Raises Questions about Pollutants Produced during Satellite and Rocket Reentry.* SpaceNews, (December 15, 2020), https://spacenews.com/aerospace-agu-reentry-pollution/.

[16] Martin N. Ross & Leonard David, *An Underappreciated Danger of the New Space Age: Global Air Pollution*, Scientific American, (February 2021), https://www.scientificamerican.com/article/an-underappreciated-danger-of-the-new-space-age-global-air-pollution/.

It is incumbent on all administrations that authorize mega-constellations to serve their jurisdictions to consider these consequences. Every nation has responsibility for actions that facilitate LEO mega-constellation deployment and cause environmental harm.

B. *Avoiding Mega-Constellations Polluting Our Dark and Quiet Skies*

LEO mega-constellations present a threat to ongoing critical scientific research in fields of optical astronomy and radio astronomy. Questions remain as to how these concerns should be mitigated. These threats exist in the form of three types of interference: satellites in the night sky reflecting sunlight that interferes with optical research telescopes; artificial radio wavelength emissions that interfere with radio telescopes at all times; and the impact on naked eye viewing of the night sky. The growing number of LEO mega-constellation trails in the sky and the disruptive nature of such events is evident in several reports. Furthermore, the aggregate effect of a fully deployed LEO mega-constellation on the visibility of the night sky and on professional astronomical observations has not been adequately considered.

The threats of LEO mega-constellations to critical astronomy-based scientific endeavors recently were addressed by a leading group of experts under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), which included representatives of the U.N. Office of Outer Space Affairs, and the International Astronomical Union, among others. Their recent report and recommendation stresses that "[c]utting edge astronomical discoveries can only continue on the basis of an unobscured and undisturbed access to the cosmic electromagnetic signals," and details why mega-constellations are a threat to astronomy.[17] As the report explains, further work to mitigate the adverse impacts on LEO mega-constellations is urgently needed, and appropriate limits must be adopted and enforced by individual national authorities.[18]

The global community, including India, has never before faced a situation where a steady stream of thousands of satellites constantly leaves trails through the sky that disrupt vital scientific research and our enjoyment of the night sky. Viasat respectfully requests that India conduct a full environmental review of the impact of LEO mega-constellations before granting market access and require suitable mitigation to reduce the negative impact on the environment, which may include limits on the number of satellites authorized to provide service.

5. Conclusion

Planning for the future requires that scarce resources, such as near-earth space in LEO, be used wisely. New technological developments and the actions of a few individual companies require rules that ensure equitable access to essential spectrum resources and shared access to orbits, a clean atmosphere, and a dark and quiet sky. Taking into account the specific guidance above,

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[17] United Nations Office for Outer Space Affairs, International Astronomical Union, IAC, NOIR Lab. *Dark and Quiet Skies for Science and Society: Report and Recommendations*. Online Workshop (December 29, 2020): 12, https://www.iau.org/static/publications/dqskies-book-29-12-20.pdf.

[18] Ibid 15, 34.

Viasat respectfully urges that the Indian administration consider a mechanism to ensure LEO satellite counts, orbital trajectories and spectrum are equitably shared among all global nations.

In addition, and prior to granting market access to a LEO satellite mega-constellation to provide service to India, Viasat recommends the Indian administration require the applicant demonstrate with a suitable showing that its system does not and will not:

- Generate unacceptable levels of interference to GSO satellites;
- Unduly constrain other NGSO satellite operators from providing competitive services;
- Pollute space or impair physical access to space by others who seek to serve India;
- Pollute the atmosphere; or
- Pollute the dark and quiet sky, impairing radio and optical astronomy, and astrophotography.

India can prevent the threats from LEO mega-constellations by thoughtfully evaluating the terms under which these mega-constellations may be allowed to provide service within its borders, and by cooperating with like-minded countries around the world to address these threats. Viasat believes it is extremely important that the Indian administration adopt appropriate policies around these issues in order to make sure that it will be able to control its own future in space through adequate access to spectrum and orbits and preventing any adverse environmental impacts from LEO mega-constellations.