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REGULATION OF NGSO SYSTEMS

(Item on the Agenda: 3.4)

(Information Document submitted by Viasat)

Impact on the sector:

This document provides critical information related to the licensing of, or grant of market access to, constellations consisting of thousands of satellites in Low Earth Orbit (LEO). It urges CITEL Administrations considering requests for such authority to address critical issues of preclusive effects on others' use of limited and shared spectrum and orbits, radio spectrum interference, and environmental impact.

Summary

The space ecosystem is changing rapidly. New geostationary (GSO) satellite systems are being designed and deployed with exciting new broadband capabilities that promise broadband connectivity opportunities for all. At the same time, LEO has become more readily accessible, and new low cost launch options are becoming available from multiple sources. LEO constellations are a way for all nations to access space, and facilitate augmentation of other national telecommunications network resources such as GSO satellites, wireless networks, data centers, and cloud centers. All nations can create new high technology jobs and participate in global efforts around LEO satellite system design, manufacture, operation, and network planning.

These opportunities are under threat by a few mega-constellations consisting of thousands or tens of thousands of satellites in LEO. The world can support only a finite number of satellites in LEO orbits. A few individual companies are attempting to seize and monopolize those limited orbital resources before the rest of the world understands those limits. Because of the very large numbers of satellites involved, LEO mega-constellations present growing concerns about: (1) interference to GSO networks; (2) interference to, and access to the same orbits by, other LEO systems; (3) space safety; and (4) environmental impact on Earth's atmosphere and skies. Below, Viasat provides background on these critical and time-sensitive issues as well as actionable recommendations for CITEL Administrations.

Executive Summary:

Viasat submits this information paper as a matter of urgency on recent developments that require immediate attention in order to ensure that (i) satellite-delivered broadband remains viable in CITEL Administrations, and (ii) the actions of a few do not damage CITEL Administrations' skies or the availability of existing or future competitive broadband options.

Viasat is dedicated to connecting the citizens of CITEL Administrations with affordable, high quality broadband services across the region. Viasat's satellites are designed to offer broadband services through ubiquitous user terminals with broadband speeds of up to 100 Mbit/s over many CITEL Administrations, including locations in cities and rural regions that are not served by traditional terrestrial services. For millions of citizens in CITEL countries living outside the "connected" portions of large cities, the broadband services of Viasat and of other geostationary ("GSO") satellite service providers are their only option to get broadband communication services at reasonable prices with good quality and in a timely fashion. Viasat will further improve the broadband available in the Americas next year, when we launch our new ViaSat-3 satellite. This satellite has more capacity than any other satellite launched to date (over 1 Terabit per second) and enables services and speeds never before possible.

At the same time, 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. All CITEL Administrations 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, they can maintain national sovereignty over the use of space to serve their territories.

These significant opportunities are under threat by a few mega-constellations consisting of thousands or tens of thousands of satellites in LEO. LEO is a shared and limited resource – a "commons" that must be protected and accessible to all. New research and modeling from multiple academics, space companies, and even the United States Federal Communications Commission, indicate that the world can support only a finite number of satellites in LEO orbits. Leading experts also recognize that LEO mega-constellation operators may not have the economic incentive to protect these shared resources. In fact, a few individual companies currently are attempting to seize and monopolize those limited orbital resources before the rest of the world understands those limits, and before the environmental consequences have been fully studied and the harms are mitigated. Moreover, many recent technological advances have eliminated the high cost of access to space that once fostered a responsible space ecosystem and limited the number of objects launched into space. The growing trend toward deploying huge numbers of mass produced, and economically expendable LEO satellites to stake exclusive claims to the best orbital assets is leading the world to a very dangerous place that also threatens the atmosphere on Earth and a dark and quiet sky that is critical for scientific research.

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,[1] 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."

The same is true for pollution in CITEL Administrations caused by other Administrations' LEO mega-constellations. It is critical that CITEL Administrations address these types of issues themselves in considering market access requests for LEO mega-constellations, and before granting their share of limited orbital resources to individual foreign companies. In particular, CITEL Administrations should consider, before granting market access, how a LEO mega-constellation can (i) constrain CITEL Administrations' 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 CITEL Administrations, and (iii) disrupt a dark and quiet sky and impair important scientific research, and (iv) pollute the environment.

As discussed in more detail below, the threats created by LEO mega-constellations include:

- Generating unacceptable levels of interference into GSOs and harming a variety of important GSO-based services.
- Constraining the ability of other NGSO satellites to provide competitive services by blocking access to critical shared spectrum and orbits.
- Creating collision risk and new space junk that impair access to space by others who seek to serve CITEL Administrations.
- Polluting our atmosphere, affecting the health and well-being of CITEL countries' citizens.
- Polluting the dark and quiet sky, affecting science-based astronomy (optical and radio) and other local activities in CITEL Administrations, like astrophotography and star gazing.

Viasat urges CITEL Administrations to evaluate, at the market access stage, ways to protect the availability of satellite broadband service offerings for CITEL country citizens and address the potential harms from LEO mega-constellations to the Americas' environment. This should include full consideration of these issues when considering market access applications, adopting suitable mitigation measures where market access is awarded, and imposing conditions that ensure the actual operation of any LEO mega-constellation is consistent with the considerations underlying any grant of authority to serve CITEL Administrations.

REGULATION OF NGSO SYSTEMS

1. Constraining NGSO Interference into GSO networks.

Newly introduced LEO mega-constellations can block other satellite operators from interference-free access to the spectrum they would otherwise share. 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."

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 that would serve

[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.

CITEL Administrations. 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 the Americas including commercial and national programs (*e.g.*, Mexsat, Brazil's SGDC-1, Bolivia's TK-1, ARSAT) in CITEL Administrations.

Today's very 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 CITEL Administrations 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 an aggregate interference problem for GSO networks by illuminating a location with multiple beams from multiple satellites and the many millions of sidelobes created by millions of user terminals and the dozens of beams on each of its many satellites.

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 19.3° N, 99.1° W (Mexico City, Mexico), a central location within the Americas, for CITEL Administrations' 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 Mexico.
- 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 system serving Mexico.
- 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	2.7%	31.2%	100%
3,000 Satellites	0%	18.5%	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 a given CITEL Administration, foreclosing competition. The threat to orbital sharing exists because LEO orbits are limited, and as leading experts recognize[2] 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 CITEL Administrations 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 CITEL Administrations, 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] *See* https://www.theverge.com/2021/1/27/22251127/elon-musk-bezos-amazon-billionaires-satellites-space.

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 the CITEL Administration;
5. Number of satellites, orbits employed, orbital tolerance and other orbital characteristics;
6. Number of total beams and number of co-frequency beams 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. Avoiding LEO Mega-Constellations Polluting Space

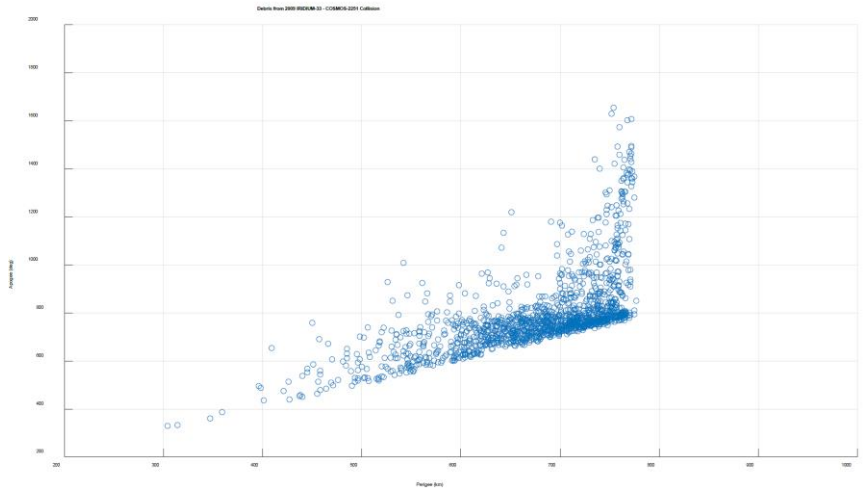
LEO orbits have become increasing littered with space junk: "The most crowded section is between 500 and 1000 km up. It's the densest region[] of space."[3] The launch of thousands, or tens to hundreds of thousands, of mega-constellation satellites into LEO increases the risk of collisions in these crowded orbits. As the Organization for Economic Cooperation and Development (OECD) recognizes[4], 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.

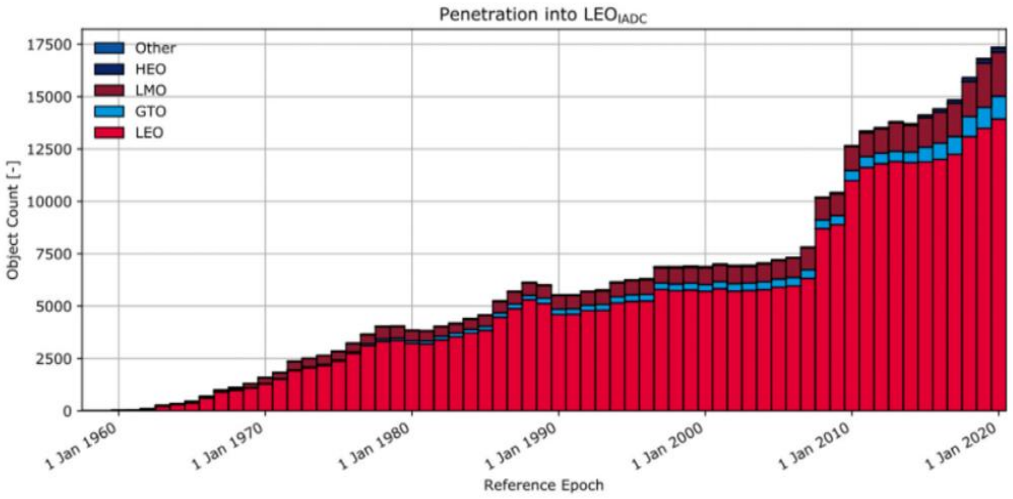
[3] Kessler Syndrome: *What Happens When Satellites Collide*, https://asherkaye.medium.com/kessler-syndrome-what-happens-when-satellites-collide-1b571ca3c47e.

[4] 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.



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-constellations.[5] A significant portion of recent increases is attributable to LEO satellites themselves, as well as the fragmentation of those satellites after collisions.[6]



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:

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

[6] Ibid 13.

- 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;[7]
- 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).

It is critical that CITEL Administrations, when considering a grant of market access for LEO mega-constellations, consider the aggregate collision risk over the entire term of exploitation, 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:

- 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 $\geq$ 10 cm and $\leq$ 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 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.[8]

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:

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[7] 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.").

[8] 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[9]

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 urges CITEL Administrations, 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 urges CITEL Administrations to 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;
- 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 urges CITEL Administrations to:

- Grant authority in stages (*i.e.*, for parts of the constellation at a time);
- Condition authority appropriately, including conditioning on confirmation that satellites are actually built and operating consistently with the representations in the application; and

[9] 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.

- Promptly act to address any material deviations that could pose an increased threat of in-orbit collisions including, but not limited to, withholding authority to serve an Administration 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.[10] Most of the re-entering mass will vaporize into small particles consisting of what experts call a "zoo of complex chemical types."[11] 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.

It is incumbent on all CITEL 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

[10] 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/.

[11] 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/.

to astronomy.[12] 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.[13]

The global community, including CITEL countries, have 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 urges CITEL Administrations to 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, are used wisely. New technological developments and the actions of a few individual companies require rules that ensure equitable access to essential spectrum resources rules and shared access to orbits, a clean atmosphere, and a dark and quiet sky. Taking into account the specific guidance above, Viasat respectfully urges that CITEL Administrations consider a mechanism to allocate LEO satellite counts, orbital trajectories and spectrum fairly among all global nations.

In addition, and prior to granting market access to a LEO satellite mega-constellation to provide service to a CITEL country, Viasat urges CITEL Administrations to 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 CITEL countries;
- Pollute our atmosphere; or
- Pollute the dark and quiet sky, impairing radio and optical astronomy, and astrophotography.

CITEL Administrations 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 their borders, and by cooperating with like-minded countries around the world to address these threats. It is extremely important that CITEL Administrations adopt appropriate policies around these issues in order to make sure that they will be able to control their destiny in space through adequate access to spectrum and orbits and preventing any adverse environmental impacts from LEO mega-constellations.

[12] 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.

[13] Ibid 15, 34.