Sept. 27, 2021

Introduction:

Viasat commends Ofcom for commencing the "Non-geostationary satellite systems: Licensing updates" consultation ("Consultation")[1] and provides responses and recommendations below to the Consultation questions.

Reliable access to sufficient spectrum and orbital resources are key drivers in the ability of all satellite technologies to meet the evolving broadband needs of UK users. By updating its licensing policies for non-geostationary (NGSO) satellite systems, including those in Low Earth Orbit (LEO) in particular, Ofcom can ensure that its policies keep pace with ongoing changes and innovations in the industry. One of the major changes that has been taking place is the development of a new generation of geostationary (GSO) satellites known as Ultra High Throughput (UHT) satellite networks. UHT satellite networks have many new features, including highly efficient spectrum reuse that yields enormous capacity, and smaller end-user terminals that are more readily deployed, but the true innovation lies in the services that these satellite networks can provide, including high-speed broadband to customers featuring speeds of hundreds of Mbit/s.

Viasat currently provide satellite-powered broadband services around the globe in a variety of frequency bands, including the Ku and Ka bands. We are preparing to deploy our next generation ViaSat-3 spacecraft in GSO to enable more affordable, faster, and more reliable service. And to continue to meet growing capacity demands, developing our ViaSat-4 class satellites, which will offer significantly greater capabilities.

Viasat also designs, builds, and operates NGSO satellites. Viasat currently operates a satellite for a U.S. Government customer in LEO at an orbit of 575 km, and has active plans to expand its fleet with additional satellites and satellite constellations. For example, Viasat has authority to serve the U.S. market with an NGSO satellite system consisting of 20 satellites operating in MEO,[2] and is seeking a modification to deploy 288 satellites at a lower altitude in LEO. In addition, Viasat is under contract with the U.S. Department of Defense to launch a high value LEO satellite that will demonstrate Tactical Data Links from space in support of the Department of Defense and Space Force. Many more such satellites are contemplated.

As Ofcom recognises with the publication of this Consultation, there is also an unprecedented introduction of NGSO systems consisting of designs that were never anticipated, some with thousands of satellites in LEO. Many of these NGSO systems present a number of new opportunities but also present significant and unanticipated threats. These threats include constraining access to the limited and shared spectrum and orbit resources long used by GSO networks and only recently starting to be used by NGSO systems.

Communications satellites have long shared access to radio spectrum by operating with "angular separation" among them so that each one operates with different lines of sight to and

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[1] *See* https://www.ofcom.org.uk/__data/assets/pdf_file/0015/222450/ngso-licensing-consultation.pdf.

[2] *Viasat, Inc. Petition for Declaratory Ruling Granting Access for a Non-U.S. Licensed Non-Geostationary Orbit Satellite Network*, Order and Declaratory Ruling, 35 FCC Rcd. 4224 (Apr. 23, 2020).

from their respective Earth stations. This long-standing spectrum sharing method, which has worked for both GSO networks and NGSO systems, is at risk from certain NGSO constellations that can consume significant portions of the "look angles" to and from space, interfering with, or blocking access to spectrum used by GSO networks and other NGSO systems, and preventing use of the sharing tools that have been used successfully for five decades among satellite system operators.

Large NGSO constellations will rarely face any material decrease in capacity because they have so many alternative look angles from which to communicate. Thus, while it is necessary to address these effects at the licensing stage to expand competitive alternatives, it bears emphasis that any regulations would not unduly restrict the operation of NGSO systems.

Serious questions are being asked not just about equitable sharing of spectrum, but also how certain NGSO systems consume disproportionate amounts of physical orbits. Specifically, Astrophysicists, scientists and regulators express grave concern about over-crowding the space closest to Earth, known LEO, explaining:

> "The rise of large LEO system poses the risk of denying access to LEO and radio spectrum by making it impossible for late arrivals to operate there safely and sustainably. 'It should concern us all and it's time to do something about it.'" [3]
>
> "It's a race to the bottom in terms of getting as much stuff up there as possible to claim orbital real estate."[4]
>
> "The grabbing-up of all the good territory is a reasonable complaint."[5]

These experts are talking about (i) loss of safe access to LEO, and (ii) monopolization of spectrum and orbits by a few actors. Their concerns reflect the reality that there are limits to what types of, and how many, satellites sustainably can occupy LEO.

These threats, if realized, can preclude other NGSO systems from operating even in different frequency bands. Further, there are questions as to how certain NGSO systems are operating in reality, not just theoretically on paper or in models. Blocking access to shared spectrum resources in this manner inhibits the ability of other NGSO and GSO systems to effectively compete.

Moreover, the twenty-year-old framework for NGSO systems that has been developed at the International Telecommunication Union (ITU) has several well-understood shortcomings and the review process for NGSO ITU filings cannot be relied upon to ensure interference-free operations where NGSO systems are involved. Therefore, national regulators, like Ofcom,

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3 de Selding, Peter "Saudi regulator: ITU must address LEO crowding, debris and sustainability before the orbit is rendered unusable." *Space Intel Report*, September 16, 2021.

4 Pancevski, Bojan, "Elon Musk's Satellite Internet Project Is Too Risky, Rivals Say." *Wall Street Journal*, April 19, 2021.

5 Roulette, Joey, "Elon Musk's Shot at Amazon Flares Monthslong Fight Over Billionairess' Orbital Real Estate," *The Verge*, January 2, 2021.

have an independent legal obligation under UK law to *prevent* radio spectrum interference from happening in the first place and to promote competition to benefit users in the UK[6]. Further, it would facilitate competition in the UK to ensure that multiple operators can equitably access space, including UK systems, rather than to simply allow one or two early entrants to monopolize orbits and spectrum.

Indeed, as Ofcom recognizes in the Consultation, it cannot "solely rely on the ITU framework to effectively deal with all concerns impacting NGSO services provided to the UK".[7] Indeed, the ITU has itself stated that compliance with the NGSO EPFD limits falls on administrations in cases where the ITU's EPFD modelling software cannot sufficiently model a particular NGSO system, and in any event remains the responsibility of administrations when it is comes down to whether NGSO systems satisfy EPFD limits during actual operation. Services to UK users will be degraded by interference if these issues are not resolved *before* NGSO systems are licensed to operate in the UK.

Safe space is inextricably intertwined with NGSO UK market access and NGSO spectrum policy cannot be made without reference to the need to ensure the integrity of communications networks that serve the U.K. by managing NGSO collision risk. As noted above, other regulators recognize that certain systems pose a risk of denying access by others to LEO orbits and radio spectrum.

The rush to claim as many resources as possible without regard to these interference, competition and safe space issues are all national licensing matters with respect to any NGSO system that serves the UK. Viasat recommends Ofcom address these looming issues to prevent interference and protect competition for UK users. Ofcom's remaining competitively and technology neutral in such decisions will promote overall growth in the satellite industry and connectivity for UK citizens. Viasat urges Ofcom to address the concerns discussed below *prior* to granting market access to NGSO systems.

Q1) Do you have any comments on our assessment of the interference challenges raised by NGSO systems and their potential impact on a) service quality; and b) competition?

Ofcom's assessment of the interference challenges raised by NGSO systems in the consultation is valid and timely given the rapid deployments of NGSO systems and changes in NGSO system design.

GSO-NGSO Spectrum Sharing

As Ofcom recognizes in the Consultation, GSO-to-GSO spectrum sharing is a relatively simple process whereby GSO network operators coordinate operations on Earth and at the GSO arc through orbital arc spacing (*i.e.*, "angular separation" between their satellites in space at fixed points in the sky relative to Earth). NGSO systems, by contrast, have fast moving satellites that create new challenges as their satellites are tracked by gateways and user terminals across the sky. These movements across the sky create opportunities for time varying interference not just

[6] *Wireless Telegraphy Act 2006*, Section 3, cited in the Consultation, Sections 2.25, 2.26, pp. 9-10.
[7] *See* Consultation at Section 3.15, p. 16.

into other NGSO systems but also into GSO networks. As is the case between NGSO systems, without appropriate mitigation measures, in-line events can occur between NGSO systems and GSO networks and repeatedly degrade and disrupt services to end users.

Today's Ka band UHT GSO satellites are extremely efficient in how they use spectrum to provide innovative services with smaller user terminals than ever possible before. Taking advantage of the advancements in technology, satellites like ViaSat-3 are capable of providing more than 1 Tbit/s of total capacity each and dynamically direct capacity and coverage where and when it is most needed.[8] And each next-generation ViaSat-4 satellite will have 5-7 times that amount of capacity. Viasat has pioneered mobile broadband services using innovative antenna designs for Earth stations in motion (ESIM) service to aircraft, ships and other land-based users. These services include gate-to-gate/port-to-port, high-speed broadband for communications and entertainment, cabin support, and fleet digitization for passengers and crew on aircrafts and ships.

Managing NGSO interference into GSO networks is critical to ensure the continuing availability and reliability of these vital GSO services in the UK. Ofcom must protect these advanced GSO UHT networks to ensure continued availability, innovation and competition. Both GSO network and NGSO system operators need regulatory certainty for interference-free sharing of spectrum, including national spectrum access, to plan their operations and services for end users.

The potential for disruption to GSO networks by co-frequency NGSO systems is well-known and is what led to the development of certain EPFD limits 20 years ago in some frequency bands based on then-existing technologies and systems designs. Current ITU Radio Regulations (RR) for protection of GSO networks from NGSO systems are a patchwork, particularly in Ku and Ka band as shown in Figure 1 below.

These provisions include:

a) RR No. 22.2 that requires NGSO systems not to cause **unacceptable interference** to, or claim protection from, GSO networks;
b) In certain frequency bands, a requirement that NGSO systems meet certain equivalent power flux density (EPFD) limits; and
c) In other frequency bands, a requirement that NGSO systems coordinate under RR No. 9.11A based on ITU network filing date priority.

8 *ViaSat-3 Satellite Constellation*, ViaSat, Inc., https://www.viasat.com/space-innovation/satellite-fleet/viasat-3/.

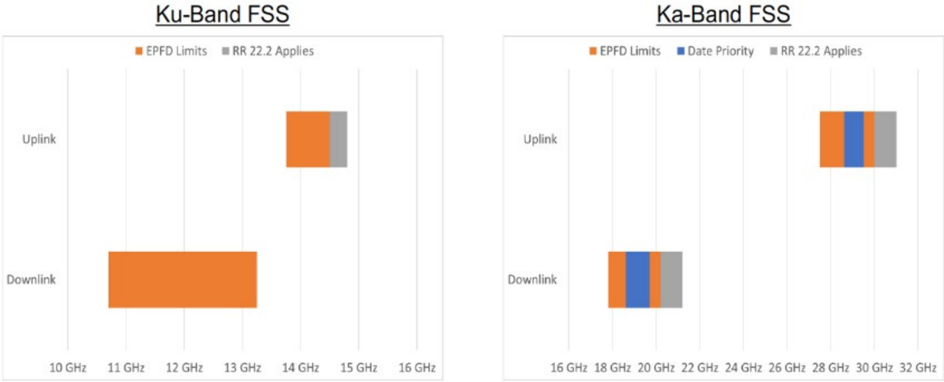

Figure 1 – *Patchwork of GSO protection rules for different bands.*

As explained further in this section, the ITU EPFD framework and associated software do not account for the multiplying effect of several underlying NGSO system issues – (1) actual NGSO system operation may not be consistent with the inputs used for EPFD validation; (2) existing Rec. S.1503-2[9] software can wrongly validate an NGSO system as complying with Article 22 limits (by use of "Worst Case Geometry") at one location even though its operations will exceed the limits in other locations; and (3) the number of NGSO systems (and their constituent satellites) that contribute to GSO network interference are far greater than anticipated when the EPFD limits were established.

Both NGSO system and GSO network characteristics have evolved significantly over the last 20 years. NGSO system EPFD limits were largely finalized in 2003 at a time when a 288-satellite NGSO system was considered large and GSO networks were capable of achieving only relatively low throughput (*e.g.*, 1 Gbit/s). Today's NGSO systems include thousands, or tens of thousands, of satellites in a variety of low Earth orbits (altitudes and inclinations). Even if a GSO network earth station is in an area illuminated by a single NGSO satellite main beam, it will receive radiation from 100's (or often 1000's) of NGSO satellite system beam sidelobes. In addition, significant questions exist about how today's NGSO system operators will be able to both calculate and actually manage the *cumulative* interference impact of the countless sidelobes created by satellite antenna beams and the sidelobes and backlobes created by NGSO user terminals.

Further, GSO networks are approaching a four-order-of-magnitude increase in capacity due in part to increased spectral efficiency which is facilitated by employing satellite receivers with low noise temperatures and high antenna gains (G/T). Today, even a single NGSO system has the potential to cause interference into GSO UHT networks. Multiple NGSO systems operating simultaneously pose an even greater risk to those GSO networks. If the NGSO communication links are not angularly separated from the GSO network arc by a sufficient angle, they could easily cause debilitating levels of service degradation and capacity losses to GSO networks.

[9] *See* ITU-R Recommendation 1503-2 (12/2013), "Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations", *superseded by* ITU-R Recommendation S.1503-3 (01/2018). The ITU EPFD compliance software has not been updated to reflect the changes from S.1503-3.

Aggregate NGSO system uplink (Earth-to-space) EPFD limits do not exist. Without them, Figure 2 below shows that the earth stations operating in the presence of an increasing number of NGSO systems can significantly degrade the service provided by advanced GSO satellites with highly efficient satellite receivers in space (high G/T).

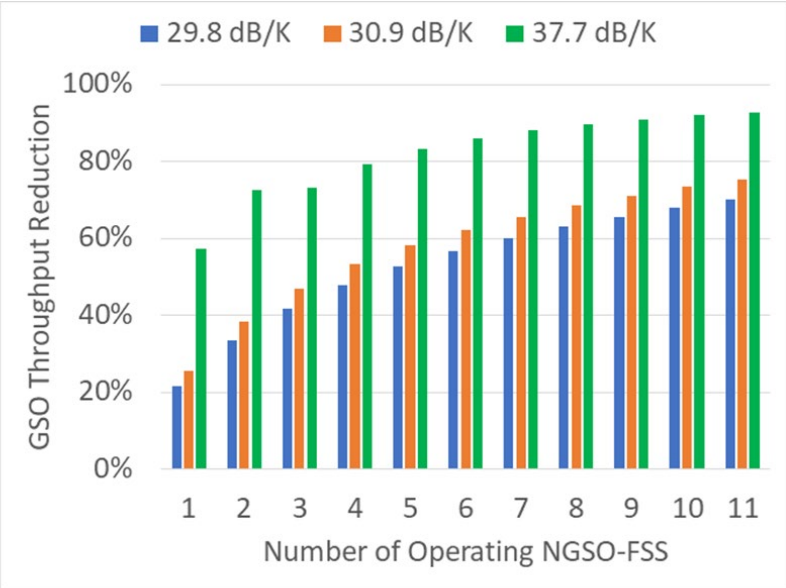

Figure 2 – *GSO throughput reduction with current EPFD up limit*.

The G/T performances shown above correspond to GSO satellite networks that are on file at the ITU and are either already deployed or planned to be launched. The throughput reduction above has been calculated using the methodology in ITU-R Recommendation S.2131 to compute percentage of degraded throughput[10].

In addition, there are inadequacies in the ITU methodology used for EPFD examination which leads to false results and is open to misuse. At the ITU, at the coordination stage, there is a process for validating whether a stated design can be expected to meet NGSO system EPFD limits specified in RR No. 22.5. There are well-recognized flaws in the ITU-R Recommendation S.1503 validation algorithm and the associated software that yield false results.

Software based on ITU-R Recommendation S.1503-2, which is used by the ITU Radiocommunication Bureau to validate NGSO system filings, contains an algorithm to derive a 'worst case geometry', a location for the NGSO system being examined and a representative GSO network that is intended to represent the highest single-entry NGSO system EPFD level. Recommendation S.1503-2 includes an algorithm to calculate NGSO system EPFD levels only for that specific location and the corresponding GSO earth station and GSO satellite. The ITU Radiocommunication Bureau validates EPFD levels for the NGSO system filing only at that one location. Notably, the GSO earth station location used in the analysis is not necessarily the worst case. Expected NGSO system EPFD at

[10] *See* ITU-R Recommendation S.2131-0 (09/2019), "Method for the determination of performance objectives for satellite hypothetical reference digital paths using adaptive coding and modulation".

locations other than the location automatically calculated by the ITU software can exceed the applicable NGSO system EPFD limits. That is, an NGSO system can appear to complete ITU EPFD validation even though it would exceed NGSO system EPFD limits and violate the Radio Regulations. This is because of a fundamental flaw in the ITU methodology and software that has been well-documented.

Examples of NGSO system EPFD violations due to flaws in ITU 1503-2 software are provided in the following analysis by OneWeb submitted to ITU-R Working Party 4A for an earth station located at Goonhilly, England. [11] This analysis addresses both Ku and Ka band downlink EPFD exceedances for STEAM-1 and STEAM-2B non-GSO FSS systems respectively, which were validated based on the flawed algorithm of ITU-R S.1503-2. The blue line shows the single-entry EPFD limits from Article **22** (Table **22-1A**) and the orange line is the actual levels of EPFD calculated at Goonhilly, England.

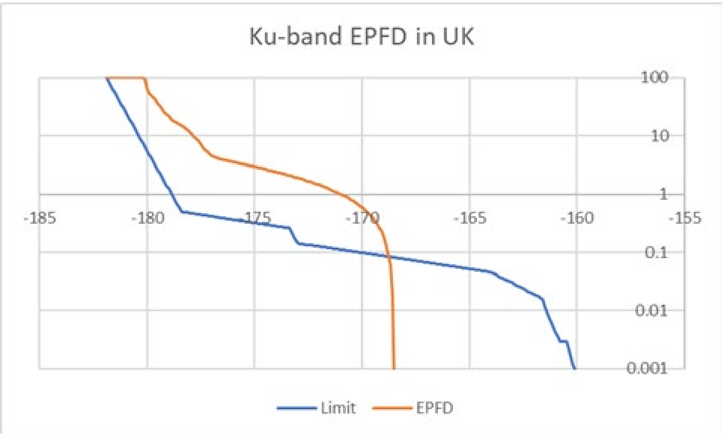

Figure 3: *Goonhilly, England Ku band NGSO system EPFD exceedances not identified by ITU-R Rec. 1503 software.*

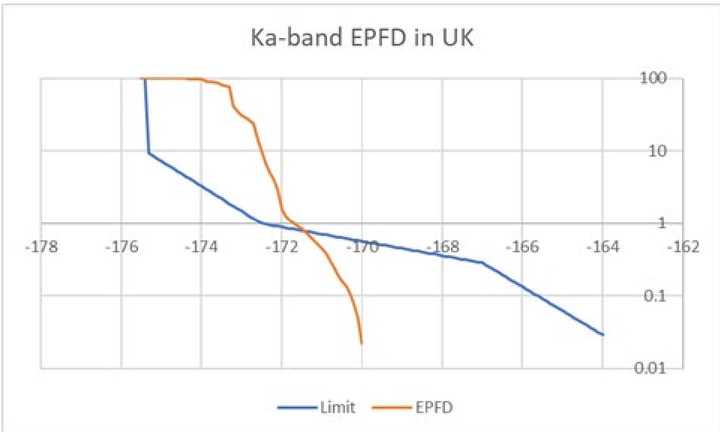

Figure 4: *Goonhilly, England Ka band NGSO system EPFD exceedances not identified by ITU-R Rec. 1503 software.*

11 *See* ITU-R Working Party 4A, Document 4A/[OW-4], (19 June, 2019), "Need for a Procedure to Deal with Cases of EPFD Exceedance that are Not Detected by the Worst-Case Geometry Algorithm in Recommendation ITU-R S.1503".

It can also be observed from above plots that, in the Ku band, the EPFD limits are exceeded for percentages from 0.1% to 100% of the time, by up to 8.5 dB. An exceedance of this magnitude also means that this system uses up the entire allowance, and more, of EPFD that is permitted in the *aggregate* for multiple NGSO systems by ITU Resolution 76[12].

In addition, NGSO operators are seeking to erode the protection provided to GSO networks by the Article 22 NGSO system EPFD limits by changing the "measuring stick" under ITU-R Recommendation S.1503. Any changes to ITU-R Recommendation S.1503 cannot be done in isolation but rather must address the overall effect and risk of interference to GSO networks by taking into account all of the known deficiencies in an outdated 20-year framework, such as the software flaw illustrated above. More fundamentally, Ofcom should factor into its licensing rules that NGSO operators have the ability to submit inputs and assumptions that yield a validation result that will not be actually realized when the NGSO system is placed into operation.

Furthermore, Ofcom has previously recognized issues raised by multiple filings of the same NGSO system in the context of bringing into use of frequency assignments for NGSO systems (*e.g.*, WRC-19 AI7 issue A, UK contribution 4A/436 to WP4A). Some NGSO systems also appear to be splitting their system into multiple ITU filings to impermissibly aggregate so-called "single entry" EPFD contributions in an attempt to generate more interference during operation than otherwise would be permitted for a single NGSO system. Some NGSO operators are operating a single NGSO system under filings made by multiple administrations for the same frequency bands, also in an attempt to generate more interference during operation than otherwise would be permitted for a single NGSO system.

The issue of *aggregate* interference into a GSO network generated by the operation of multiple co-frequency NGSO systems also requires careful scrutiny by Ofcom. As illustrated above in Figure 2, in the uplink direction, even a single NGSO constellation has the potential to cause unacceptable (and even harmful) interference into GSO networks, resulting in significant degradation and capacity losses for GSO networks that serve the UK. Multiple NGSO systems operating simultaneously pose an even greater risk to GSO networks. This can significantly degrade the provision of critical GSO-based services in the UK.

The same is true in the downlink direction. The single entry NGSO system EPFD limits in Article 22 were derived assuming only 3.5 NGSO systems operating simultaneously. As it stands, there are many more than 3.5 NGSO systems filed at the ITU today and a number of those NGSO systems are already being deployed. Resolution 76 provides aggregate EPFD↓ limits that must be applied in this case. In accordance with *resolves* 1 and 2 of Resolution 76, administrations are required to take all possible steps, including, if necessary, modifying NGSO system operations to ensure that aggregate NGSO system EPFD limits are not exceeded and in the

[12] ITU Radio Regulation, Resolution 76 (Rev. WRC-15), "Protection of geostationary fixed-satellite service and geostationary broadcasting-satellite service networks from the maximum aggregate equivalent power flux-density produced by multiple non-geostationary fixed-satellite service systems in frequency bands where equivalent power flux-density limits have been adopted".

event of exceedance, taking all necessary measures expeditiously to reduce the *aggregate* NGSO system EPFD levels.

It is critical to address and prevent the potential for aggregate interference into GSO networks from the operation of multiple NGSO systems that serve the UK. It is also important for Ofcom to ensure there is an effective mechanism in place so it can require NGSO operators serving the UK to reduce transmissions across multiple NGSO systems to prevent such interference to other satellite systems and networks also serving the UK. Viasat urges Ofcom to address this issue as part of its processes for licensing NGSO systems to serve the UK.

There are additional interference matters that are not assessed as part of the ITU's validation of an NGSO filing, and which require analysis at the national level and as part of Ofcom's NGSO system license review process, *prior* to any grant of authority to serve the UK. Namely, the ITU does not conduct a compliance check against "operational" and "additional operational" NGSO system EPFD limits which must be met to fulfil NGSO system obligations under the ITU Radio Regulations. The "operational" and "additional operational" NGSO system EPFD limits protect GSO networks from synchronisation loss, which can cause extended periods of service outage, as a result of high levels of interference from NGSO systems for a short period of time. A commitment from NGSO operators to meet the "operational" and "additional operational" EPFD limits without any evidence or analysis that they actually can do so has the potential to cause adverse impacts on GSO network services and UK users. Again, the regulatory examination and validation of ITU filings that the ITU conducts under RR Nos. 9.35 and 11.31 with respect to the single entry EPFD limits in the ITU Radio Regulations, Tables 22-1A-E, 22-2 and 22-3 *simply does not address this issue***.**

Aside from the above issues with the NGSO system EPFD limits framework and the flawed validation process described above, those provisions apply only in certain shared bands and not others, as depicted above in Figure 1.

More specifically, the NGSO system EPFD limits do not apply in certain frequency bands *e.g.*, 20.2-21.2 GHz and 30-31 GHz. In these bands, ITU RR Article No. 22.2 prohibits 'unacceptable interference' from *any* NGSO system. Therefore, Ofcom must apply appropriate conditions to protect GSO networks for the potential of receiving unacceptable interference from NGSO systems that serve the UK.

Other portions of Ka band, for example, the 28.6-29.5 GHz and 18.8-19.7 GHz bands, are subject to coordination between NGSO systems and GSO networks under Article 9 of the ITU Radio Regulations, with later-filed NGSO systems bearing the obligation not to cause more interference than specified in various ITU-R Recommendations. For example, in the case of uplink (Earth-to-space) NGSO system interference into GSO satellite receivers in space, the levels in Figure 2 would be not only unacceptable but also harmful, and warrant specific measures to be taken when considering any request for authority to serve the UK by an NGSO system.

Viasat appreciates the steps that Ofcom has taken in the past and proposes to take in the future to facilitate and encourage cooperation and coordination between various users of spectrum for satellite services. As elaborated in the next section, Viasat believes that mitigating interference through domestic licensing conditions is essential and that Ofcom cannot rely on these issues being resolved solely through coordination. Therefore, Viasat urges Ofcom to adopt the national NGSO system licensing requirements discussed in respnses to Questions 2, 4, and 5 to facilitate coexistence among GSO networks and NGSO systems.

Because they are inextricably related, Viasat addresses the following questions 2, 4 and 5 together. Question 3 is addressed separately further below.

Q2) Do you have any comments on our approach to dealing with the interference challenges raised by NGSO systems?

Q4) Do you have any comments on the proposed updates to existing and new NGSO network licences?

Q5) Do you have any comments on the proposed updates to existing and new NGSO gateway licences?

Managing interference

Viasat notes the two measures that Ofcom proposes to manage the risk of interference from NGSO systems and recommends that Ofcom apply similar and additional measures for managing the risk of interference from NGSO systems into GSO networks.

In the frequency bands where EPFD limits do apply, since the calculation of NGSO system EPFD levels and compliance with those limits is based on complex models and simulations, it is necessary to ascertain whether the models and simulation represent actual operations of NGSO systems as they are deployed. Viasat urges Ofcom to not solely rely on ITU-R Recommendation S.1503 software to assess the interference environment created by NGSO systems. Software-based EPFD validation through the ITU process is only as accurate as the inputs provided by NGSO operators. In order to generate meaningful and accurate NGSO system output EPFD levels, at the Ofcom license application and modification stages, inputs like actual orbital characteristics, operational parameters, EIRP and PFD masks need to be provided by the applicant and closely examined for their validity and consistency with respect to the technical characteristics and operation of NGSO systems. For example, it is important for national regulators like Ofcom to require that NGSO operators provide appropriate and necessary information and demonstrate at the Ofcom license application and modification stages how their systems, specifically those that implement phased arrays, will meet the EIRP and PFD input masks they provide for EPFD validation considering off-axis performance of the antennas across all steering angles, planes and geometries.

While ITU-R recommendations have been developed to assist administrations in measuring aggregate EPFD↓, they are not effective in measuring single entrant EPFD↓ once multile systems have become operational, as it is impossible to differentiate between emissions from the individual systems. Hence, there is no possibility of directly measuring single entrant EPFD↓. The same applies to single entrant EPFD↑ measurements. Neither can be measured, they can only be calculated. The formula for doing so in provided in RR 22.5C.1, per RR 22.5D.1, the same formula is used for both EPFD↓ and EPFD↑.

In order to mitigate the risk of interference to GSO networks licensed by or serving the UK, it therefore is critical to address this threat at the licensing stage, rather than hoping it can be addressed after NGSO operations commence. Viasat therefore recommends that Ofcom address its responsibility for preventing radio interference by (i) analyzing and modelling the proposed NGSO systems' operating parameters based on their actual satellite network designs, gateways, and user terminal technology per the application and authorization requirements described below, and (ii) conditioning any grants of authority appropriately.

1. Ofcom must require that NGSO systems serving the UK maintain suitable "angular separation" or "avoidance" from the GSO arc, consistent with NGSO system ITU filings, with the separation angle depending on particular attributes of the NGSO system and GSO networks. GSO arc avoidance is a mitigation technique used by NGSO systems to protect GSO networks and can be defined as a non-operating zone in the field of view of a NGSO system satellite (see depiction below in Figure 5). Such angular separation must be maintained with respect to *all* frequency bands that the NGSO system applicant intends to use that are shared with GSO networks. It is important to note that angular separation imposes virtually no constraint on NGSO system capacity as large NGSO systems always have multiple options for assigning different satellites to serve different locations on the Earth. Also, angular separation is routinely used and accepted in ITU coordination agreements to protect GSO networks.

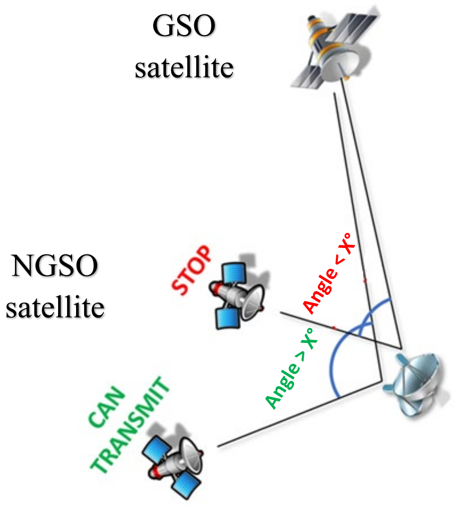

Figure 5 – *GSO avoidance angle.*

2. If, despite measures being taken by an NGSO system licensee, interference into GSO network occurs, the obligation to assess and resolve any such interference

should be placed on the NGSO systems and the interference could be addressed in a variety of ways (*e.g.*, increasing angular separation, reducing power, shaping antenna beams differently).

3. All applications for NGSO licenses must be analysed by Ofcom, as a whole, single system, even if they are operated under, or are comprised of, multiple ITU filings, including filings from different administrations. A single NGSO system should not be allowed to consume more than the interference allowance for a single NGSO system.
4. Ofcom also should address the *aggregate* interference impact on GSO networks serving the UK from multiple NGSO systems that are considered for licenses. For downlink aggregate EPFD, this can be done by assessing compliance with aggregate EPFD down limits. Until aggregate uplink aggregate EPFD limits are developed, Ofcom should apply an appropriate aggregate interference threshold (*e.g.*, ITU-R S.1323)[13] to be met collectively by all NGSO systems that serve the UK.
5. If there is an aggregate interference problem, then the burden to resolve the interference must be equitably apportioned among *all* NGSO operators that serve the UK.

The approach and requirements proposed above to deal with the NGSO system interference threats, along with Viasat's recommendations for improving the Ofcom proposed gateway and network license application process, as described in our response to question 3, will alleviate interference problems for Ofcom that are almost certain to otherwise occur given the deficiencies and inadequacies of the existing (and outdated) ITU regime for NGSO system protection of GSO networks.

NGSO-NGSO Spectrum Sharing

Viasat supports Ofcom's efforts to ensure the provision of NGSO services within the United Kingdom by multiple NGSO systems. Without proper regulation and oversight, Viasat is concerned that a few NGSO systems may be able to preclude access to both spectrum and orbital resources by other NGSO systems, to the detriment of competition that otherwise would benefit UK users.

Some existing and proposed NGSO constellations can consume significant portions of the "look angles" toward space, and essential LEO orbits, preventing use of the sharing techniques described above that have been employed successfully for decades *among* NGSO systems. This threat to NGSO spectrum sharing and competition arises because some LEO constellations will "blanket the sky," causing many in-line interference events limiting and sometimes completely blocking look angles for other NGSO systems that seek to share the same spectrum. These LEO

[13] *See* ITU-R Recommendation S.1323-2 (2002), "Maximum permissible levels of interference in a satellite network (GSO/FSS; non-GSO/FSS; non-GSO/MSS feeder links)* in the fixed-satellite service caused by other codirectional FSS networks below 30 GHz". (* The methodologies for determination of short-term interference criteria contained in this Recommendation are intended to address interference to GSO/FSS, non-GSO/FSS and non-GSO/MSS feeder links. However, the applicability of these methodologies for all such networks requires further verification).

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 look angles where the same spectrum remains available to the much larger constellation. This dynamic has been acknowledged and studied for years, and the following conclusions were reached with respect to an exemplary LEO constellation size of 4,425:

> This […] results in strong interference towards other NGSO systems, where traditional interference mitigation techniques like look-aside may perform poorly. Specifically, look-aside can be beneficial for large constellations, but detrimental for small constellations. Furthermore, we confirm that band-splitting among satellite systems significantly degrades throughput, also for the Ku-band. Our results overall show that the complexity of the inter-satellite interactions for new NGSO systems is too high to be managed via simple interference mitigation techniques. This means that more sophisticated engineering solutions, and potentially even more strict regulatory requirements, will be needed to ensure coexistence in emerging, dense NGSO deployments.[14]

Table A below describes various NGSO system sizes and the preclusive effects that would occur on certain types of large constellation configurations, in the absence of suitable mitigation measures, and measured in London. The negative effect of these large constellations can be seen 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 51.5° N, 0.1° W (London). Several observations can be made:

1. A 30,000 satellite NGSO system will blanket the sky, blocking all other constellations, including other similarly sized constellations.
2. Even 3,000-satellite NGSO systems have a significant blocking effect on many other constellations.
3. 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	4.8%	80.0%	100%
3,000 Satellites	0%	43.8%	100%
30,000 Satellites	0%	0%	100%

Table A: *Preclusive effects of various sizes of NGSO systems.*

14 *See* C. Braun, A. M. Voicu, L. Simić and P. Mähönen, *Should We Worry About Interference in Emerging Dense NGSO Satellite Constellations*?, 2019 IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN), Newark, NJ, USA, 2019, pp. 1-10, doi: 10.1109/DySPAN.2019.8935875.

Some NGSO operators seek exclusive spectrum rights across all look angles to/from a given location (*e.g.*, from a given location, tens of their satellites are within view with a 4,408-satellite constellation, and hundreds with a 30,000-satellite constellation).

Another way to view this is with the charts below. At a given (static) moment in time, it may appear that certain "look angles" from a location on Earth are available (Figure 6), but over a mere 5 minutes, it is apparent that it is virtually impossible to find available look angles any longer (Figure 7). Even for the static case, it is difficult to find "look angles" because for every dot in the Figure 6 which represent satellites of the system, one has to take into account a preclusion zone around it created by an angular separation that is needed to avoid interference. It is thus easy to see how one operator could, in fact, monopolize virtually all of the available spectrum resources.

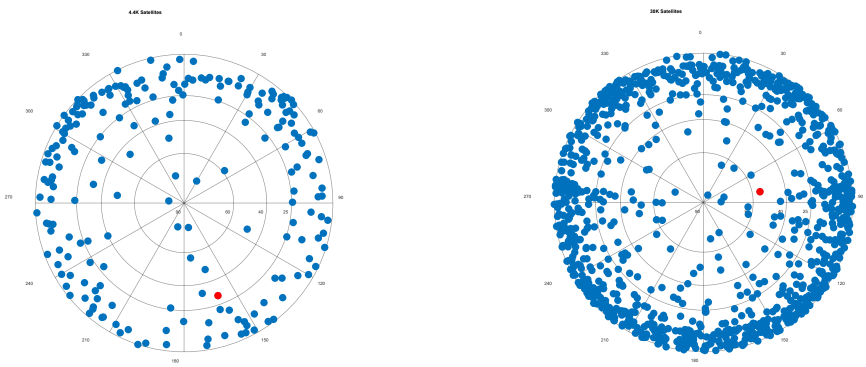

Figure 6: *Satellites in view from a given location*.

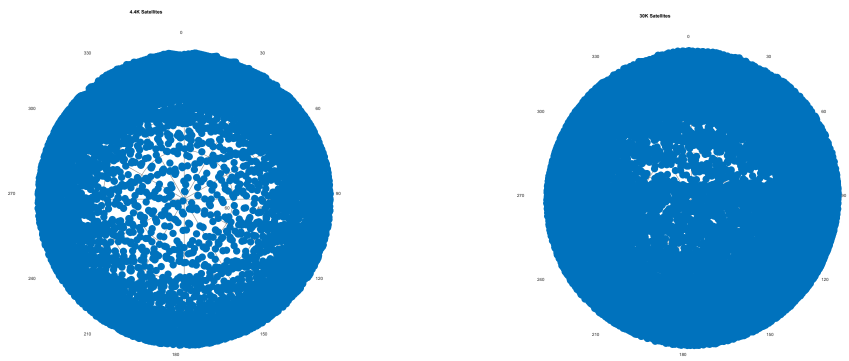

Figure 7: *Satellites Positions over 5 minutes: 4,400 satellites and 30,000 satellites on orbit.*

This dynamic has the perverse effect of incentivizing a race in which NGSO operators deploy many more satellites than actually needed, utilizing large numbers of spectrally-inefficient satellites that operate at unnecessarily large orbital tolerances, as we discuss further below, that would block shared use of the same orbits. It also creates an incentive to reject 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 LEO systems with the ability to serve the UK, foreclosing competition.

For example, take the case of a system using NCO=1, the basis for at least one filing at the ITU. Using a system value of NCO=1 means that *only one satellite in that constellation is in view at any one time* providing service to the area around that location on Earth. This is depicted though the red dots in Figure 6. If Ofcom were to base a license on the mere *possibility* of this operator providing service in that location using other satellites at the same time (which it cannot do), that would prevent other operators from using the same spectrum at different look angles in that same location on Earth.

Separately, there are also proposals being put forward by some operators for how to address access to spectrum *among* NGSO systems. Some operators have advocated "band splitting" during in-line events between satellites and earth stations in different NGSO systems. For example, under this approach, if there are "N" NGSO systems serving the same area, then each would have access to 1/N of the band when their satellites are in-line. This is not an equitable solution as it favors the NGSO system with the largest number of satellites. At the same time, the larger NGSO system would have more satellite diversity allowing it to use alternative look angles to at which it could use the same spectrum. The smaller systems (with fewer satellites in view) would be at a disadvantage if they were required to band split with *all* of the larger constellation's satellites that are in view.

Viasat recommends that, if coordination is not achieved among NGSO systems, Ofcom equitably allocate spectrum among NGSO systems during "in-line" blocking events when serving the UK, by requiring the affected NGSO systems to *equally split "look angles"* during those events rather than splitting spectrum bands per se. If there are N systems serving the same area, then each system would only be allowed to use 1/N of the "look angles". The same level of "look angle" splitting would occur regardless of the number of satellites in a given NGSO constellation. This approach allows equitable access for multiple NGSO systems and ensures the potential for competition in serving UK consumers, without providing undue advantages to larger systems.

NGSO-NGSO Orbital Resources

The threat to orbital resource sharing exists because LEO orbits are limited, and as discussed above, certain NGSO constellation operators are "grabbing-up…all the good territory"[15] in a race to consume a wide swath of the "best" orbits (in the 300 km to 650 km range). And they are doing so by seeking authority to operate with unnecessarily wide orbital tolerances, which would effectively fill up hundreds of kilometres of orbits to the exclusion of other NGSO systems who otherwise could operate alongside them.

The preclusive effect extends not only to other NGSO systems who seek to operate in the same spectrum, but also to NGSO systems who seek to operate in *different*

[15] Roulette, Joey, "Elon Musk's shot at Amazon Flares Monthslong Fight Over Billionairess' Orbital Real Estate," *The Verge*, January 2, 2021.

spectrum from nearby "lanes" in space. There is growing concern that these resources will be monopolized preventing future competition by operators within the UK and globally. This problem is depicted in the following Figures 8 and 9, which shows how an unnecessarily wide orbital tolerance prevents other satellites from sharing NGSO orbits, and how narrowing the authorized "lanes" in space can accommodate many other NGSO networks, much like separate lanes on a wide motorway allow many vehicles to operate alongside each other.

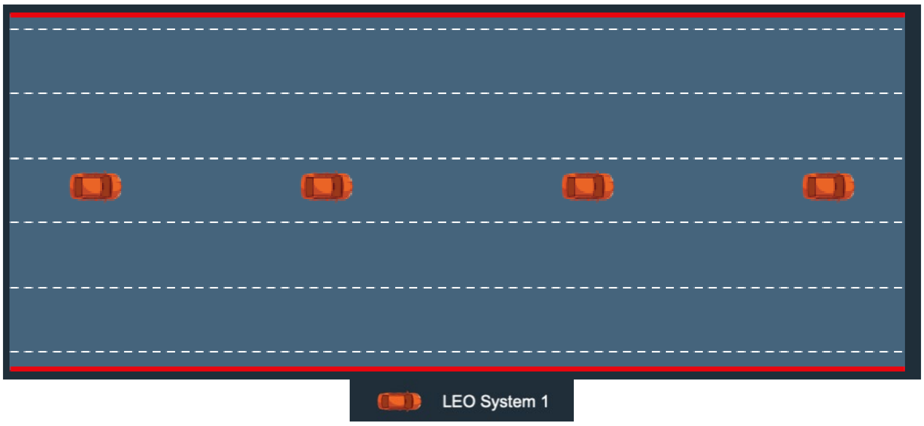

Figure 8: *With wide orbital tolerances a single NGSO constellation consumes far too many orbits*.

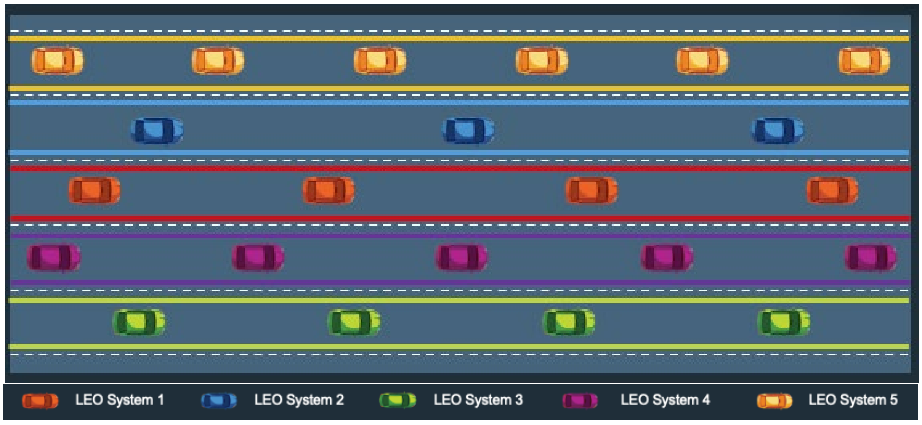

Figure 9: *With reasonable orbital tolerances, many NGSO systems can share limited orbits*.

Given that LEO constellations must (and already do) operate with much greater precision to avoid collisions, there is no good reason to allow LEO constellations to provide service utilizing overlapping shells of satellites in very wide orbits that unduly consume what otherwise would be shared.

Consistent with Ofcom's goal of a competitive marketplace, Viasat recommends that Ofcom require NGSO system applicants to (1) provide the number of satellites, orbits employed, orbital tolerance and other orbital characteristics as part of the application process and, (2) station-keep within ±2.5 km apogee and perigee tolerances and a ± 0.1 degree inclination tolerance for each orbital plane to allow for multiple NGSO systems to operate within these limited and shared orbits.

Ensuring Safe and Sustainable Uses of Space

As discussed above, safe space is inextricably intertwined with NGSO UK market access and NGSO spectrum policy cannot be made in a vacuum.

Ofcom has a legal mandate to protect the integrity of communications systems serving the UK.[16] Because orbital debris can negatively affect the reliability, continuity and use of a satellite systems' radio communications, and because spacecraft are controlled by radiofrequency links, there is a direct connection between Ofcom's responsibility to oversee radiocommunications and the physical operations of spacecraft. Moreover, Ofcom itself has recognized that there is an orbital debris problem that must be addressed.[17]

LEO orbits have become increasingly littered with space junk: "The most crowded section is between 500 and 1000 km up. It's the densest region […] of space."[18] The launch and operation of certain LEO constellations, particularly when their satellites fail before being deorbited, and have certain physical characteristics (*e.g.*, large cross-sectional areas and mass), significantly raises the risk and consequences of collisions in space. As the OECD recognizes[19], suitable measures must be put in place now, before it is too late, to prevent a so-called "tragedy of the commons."

The externalities created by the new NGSO systems that are being deployed are being passed on to other operators, be they other satellite broadband operators, or the science, defence, navigation, astronomy and other industries whose operations in these orbits are critical to the UK. The increased collision risk that is presented by the design and operation of NGSO systems drives up the cost of access to space for everyone. In fact, cost/safety trade-offs are being made today in certain LEO constellation designs, and those commercial decisions impair other uses of space by reducing the likelihood of successfully manoeuvring to avoid collisions. Economic incentives for some individual industry actors are not adequate to compel them to adopt responsible practices designed to ensure that the shared orbital environment remains available for all to use safely. Instead, these actors are motivated to adopt practices that force other space users to bear significant negative externalities, raising their economic costs and ultimately jeopardizing the viability of certain parts

[16] Communications Act of 2003, Part I, Section 3: General Duties of OFCOM, 4 "OFCOM must also have regard, in performing those duties, to such of the following as appear to them to be relevant in the circumstances—… (ea) the desirability of ensuring the security and availability of public electronic communications networks and public electronic communications services".

[17] *See* United Kingdom input to CPG PTB-3, Doc. PTB(21)INFO 05, Subject: Regulatory Provisions for TT&C frequencies for in-orbit service missions, "Active debris removal and end-of-life services have attracted the interest of governments and public agencies because of their potential to mitigate the space debris problem".

[18] Isbrucker, Asher, "Kessler Syndrome: What Happens When Satellites Collide." *Medium,* November 2, 2018.

[19] 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 space and, for Ofcom's purposes, threatening the integrity of the radiocommunications that serve UK users.

Managing Risks of Collision

Before recommending ways to manage the risk of NGSO collisions at the Ofcom licensing stage, it is helpful to consider the historical consequences of collisions involving much smaller NGSO constellations than those being considered in this Consultation.

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, 1,427 of which still remain in orbit 12 years later (see Figure 10 below), not to mention the countless smaller pieces of debris which cannot be tracked but still pose a lethal threat to other space assets. The nature of certain LEO constellations being deployed today dramatically increases the probability of these types of collisions.

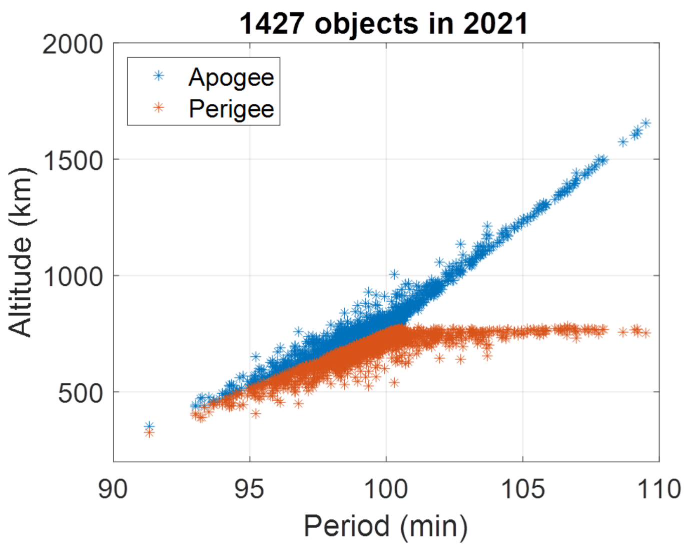

Figure 10: *Spread of Space Junk from Iridium-33/Cosmos-2251 Collision*.

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 11 from the ESA depicts the growing amount of space objects in LEO, even before the introduction of today's LEO constellations.[20] A significant portion of recent increases is attributable to LEO satellites themselves, as well as the fragmentation of those satellites after collisions.[21]

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

[21] *Ibid* 13.

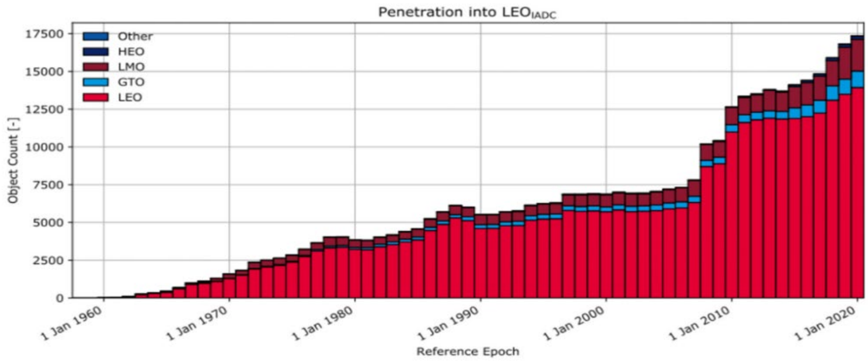

Figure 11: *ESA Growth of Space Objects in LEO*.

The risks associated with two LEO constellation satellites (or a LEO 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 kilometres per second at the intersection of their orbital paths.[22]
- How a significant fraction of the resulting space junk would periodically cross the orbital planes of the LEO constellation involved in the collision.
- How the resulting space junk would spread to other orbit altitudes (as shown in the example above).

Ofcom should assess the *aggregate* collision risk presented by *all* NGSO systems to serve the UK. Collision risk scales with factors such as surface-to-area ratio of the NGSO satellite, satellite mass, and satellite failure rates as it relates to manoeuvrability. There is an additive risk from each satellite in an NGSO system and each replacement that could be launched over the entire term. An aggregate collision risk calculation should factor in both the risks associated with satellites that fail and no longer can manoeuvre, as well as the residual risks associated with large numbers of conjunctions with space debris and other active satellites that can be expected over a license term. This is the case because a large number of even very low probability events (conjunctions that are avoided only if a certain risk threshold is exceeded) means multiple collisions can be expected over that timeframe. An appropriate evaluation of the entirety of the collision risk for an NGSO system as a whole would include taking into account:

- Collision risk at all of the orbits an NGSO satellite may populate during its lifetime;
- Collision risk due to known changes in the orbital environment (*i.e.*, the deployment of additional NGSO systems);
- Collision risk with all sizes of space objects (not just those ≥ 10 cm and ≤ 1 cm);

[22] 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 reliability of critical satellite capabilities needed to avoid collisions;
- Mass and cross-sectional area of satellites in an NGSO system;
- The risk of intra-system collisions within an NGSO system (particularly with failed satellites within that system); and
- Known risks with large numbers of expected conjunctions over the orbital lifetimes of the satellites and all of their replacements in that NGSO system.

Some NGSO system 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 license term 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 an NGSO system 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 in Table B below:

# 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 B: Collision Risk Scales with NGSO System Size[23].

Some NGSO system operators also 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 manoeuvre 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 manoeuvered 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 constellation satellites presents undue risks to space and everyone who seeks to utilize space.

In addition, and as NASA has recognized, any automated collision avoidance system must be coupled with the capability to coordinate effectively with other operators in near-real-time so as "to ensure that intended manoeuvres by either or both operators, if executed, do not place both satellites on a collision course."[24] But

[23] 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.

[24] *See NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, NASA/SP-20205011318, at 29 (2020) ("*NASA Handbook*").

as third parties have noted, some NGSO system's collision avoidance processes do not incorporate this capability; rather, they incorporate features that are likely to frustrate inter-operator coordination and *exacerbate* potential collision risks. [25] Indeed, one NGSO system operator recently disclosed that its existing collision avoidance process: (i) does not incorporate any check to ensure that a planned manoeuvre to avoid one potential collision does not create an unacceptable risk of collision with other space objects (*e.g.,* another manoeuvrable satellite or orbital debris); and (ii) does not require interaction between operators prior to "autonomous" action by one or more NGSO satellites.[26]

Finally, limits exist on the nature and number of satellites that can sustainably occupy LEO. Those limits depend on details of each system. The size of satellites is a significant factor in determining collision probabilities and how much space junk they can create when they collide with each other, with other satellites, and with the growing amount of space debris. A US National Science Foundation study by MITRE Corporation predicted the effects of just one individual LEO system already being launched and planning to deploy over 40,000 satellites at about 600 kilometres altitude. Their analysis forecasts dramatic increases in space collisions, and new debris, starting within just a few years. Longer term, the study concludes: "satellites are destroyed (by debris and collisions) faster than they are launched."[27]

Viasat recommends that Ofcom ensure that all applicants asking for authority to serve the UK by an NGSO system demonstrate their ability to (1) effectively manoeuvre to avoid collisions (and not create additional debris), (2) deorbit satellites prior to loss of manoeuvrability,, to and (3) satisfy an *aggregate* collision risk standard for a constellation as a whole (including replacement satellites) for the entire term of the license, considering the nature of their system, the evolving debris environment and the number of conjunctions (close calls) expected to be encountered with other space objects, considering all the factors outlined above. In addition, Viasat recommends that NGSO systems authorized to serve the UK be required to maintain the system's "footprint" as was applied for (including, orbits; number of satellites; satellite mass, cross-sectional area, and other dimensions) for the entirety of its license term, and reflecting the satellites actually built and launched and the extent to which they actually perform in accordance with the characteristic represented in the application.

In order to reduce the risks of interruption to radiocommunications from debris created by NGSO or collisions in which they are involved, it is necessary to limit the collision risks associated with the deployment of NGSO systems. Doing so is critical before more NGSO satellites are launched lest they have serious immediate

[25] *See generally* https://twitter.com/planet4589/status/1429525312577183746 (providing various criticisms about autonomous collision systems, *e.g.* "So, the piece that seems to be missing - at least from this depiction - is the critical aspect of maneuver screening. You might plan a maneuver to mitigate a conjunction, only to create a worse situation. The burn plan needs to be screened against the catalog prior to execution.").

[26] *See* Letter from SpaceX to FCC, IB Docket No. 18-313, Att. B (Aug. 10, 2021).

[27] *See JASON, The Mitre Corp., The Impact of Large Constellations of Satellites*, November 2020, updated January 21, 2021, at 97.

and long-term consequences – for important scientific projects, for communications networks, for other productive uses of space, and for innovation in space going forward.

Lastly, the rapid increase in satellites in LEO has created challenges in the launch industry decreasing the opportunities within launch windows for a safe transfer through LEO orbital shells to final orbits.[28] Some operators have already had close calls within these dense LEO orbits that required immediate action to mitigate a potential collision.[29] We bring this to Ofcom's attention and encourage Ofcom to work with UKSA to minimize such occurrences, and provide ample opportunity for multiple launch providers to maximize launch opportunities as this industry continues to grow.

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As detailed above, great uncertainty exists about the ability of large NGSO constellations to operate as intended, and in doing to (i) protect GSO networks from interference, (ii) equitably share spectrum and orbits with other NGSO systems, and (iii) create no more than a reasonable level of additional collision risk.

Viasat therefore recommends that Ofcom:

- Require that an applicant demonstrate at the application phase how its NGSO system would be designed, built, and operated over its orbital life consistent with these requirements, detailing the assumptions that underlie that analysis;
- Grant authority to serve the UK in stages (e.g., for phases of the system as it is launched over time---a maximum number of satellites at a time);
- Condition authority on confirmation that the satellites launched are actually built and performing on-orbit in a manner consistent with that analysis; and
- Promptly take appropriate action to address any material deviation from the bases for those grants of authority.

Doing so provides for a process of "check-ins" between licensees and Ofcom. Ofcom can assess whether an NGSO system is operating as represented in the application to Ofcom, in accordance with Ofcom policies and license conditions, and otherwise in a manner that ensures shared and equitable use of the limited spectrum and orbital resources for the benefit of UK users. In particular, Ofcom can assess the spectrum interference, including EPFD compliance for protection of GSO networks, and spectrum access for GSO and NGSO systems. And in conjunction with the UKSA, Ofcom can assess the failure rates of NGSO satellites, the efficacy of manoeuvrability capabilities, and the overall collision risk of the NGSO system, so others do not bear the costs associated with the failures of that NGSO system and UK users have access to reliable and competitive communications. Where these

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[28] *See Aviation Week, Podcast,* June 24,2021, https://aviationweek.com/defense-space/podcast-interview-ulas-tory-bruno.

[29] Hancock, Sam, "SpaceX: Elon Musk Satellite Came Within 60M With Another Owned by British-backed Firm". *Independent*, April 14, 2021.

"check-ins" suggest non-compliance or elevated risk, Ofcom would be able to timely and effectively impose additional conditions or modify its grants of authority to address the non-compliance and mitigate that risk---before the constellation is fully deployed.

Q3) Do you have any comments on the proposed updates to our process for NGSO gateway and network licences?

Viasat supports the open process proposed by Ofcom to process NGSO gateway and network license applications based on a) evidence of co-existence with other systems and b) the impact on competition. In order to realise the full benefits of this type of process, Viasat recommends following specific improvements.

In order for Ofcom to undertake its own analysis regarding co-existence between an applicant's NGSO system and other NGSO systems and GSO networks, and for stakeholders to provide accurate and meaningful comments, Ofcom must require the NGSO system applicant to provide information about the whole NGSO system. This whole-of-system information is necessary to permit evaluation of complete operational characteristics and the radio frequency environment impacts (*e.g.*, number of satellites, orbital characteristics, frequencies, beams, EPFD related inputs). As Ofcom recognises in Section 5.9 of the Consultation, cooperation between different NGSO systems, taking into account their entire systems, is necessary to determine how systems can co-exist. Therefore, knowledge of the whole NGSO system --- not just individual filings or pieces --- is necessary to assess co-existence with other systems. The same principle, albeit for the less complex GSO-GSO coexistence case, is applicable to GSO licence applications with Ofcom that require specific information about GSO satellite networks, including the longitude of the GSO satellite.

Given the nature of NGSO system operation, Ofcom should also require NGSO system operators to provide the below technical and operation information at a minimum in order to facilitate assessment of coexistence with other NGSO systems and GSO networks:

a. Earth station and satellite transmit power density;
b. Minimum angle of separation from GSO networks and other NGSO systems;
c. Off-axis gain and EIRP density mask for earth stations (gateways and user terminals) and satellite antennas;
d. Identification of whether the earth stations are user terminals or gateways and how many of each class will be deployed within the UK;
e. Number of total beams and number of co-frequency beams on each satellite; number and size of channels on each beam;
f. Number of co-frequency satellites serving a location on the Earth in the uplink and the downlink directions; and
g. How the NGSO system will operate to avoid creating an aggregate interference problem created by the many sidelobes and backlobes emitted by its user terminals and the many sidelobes emitted by its satellites, particularly when phased array antennas are employed.

The above information should also be required if an NGSO license applicant submits a variation request or modifies its NGSO system. Ofcom should also define the authorized parameters of any NGSO system approved for operation in terms of frequency usage when serving UK and to verify and ensure compliance with those operational parameters.
Q6) Do you agree with our proposal regarding NGSO terminals operating in Ka band? Viasat supports Ofcom's proposal to remove the existing exemptions for NGSO system user terminals and instead requiring that they be operated under a network license, in- line with NGSO systems with Ku band user terminals. Any authorization of NGSO terminals needs to take into account the interference issues discussed above, including the *aggregate* impact of earth station sidelobes and backlobes on GSO networks. That impact cannot be fully assessed if NGSO user terminals are license-exempt.