September 25, 2020

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Viasat, Inc. Notice of *Ex Parte* Presentation, IBFS File No. SAT-MOD-20200417-00037

Dear Ms. Dortch:

Viasat responds to recent *ex parte* presentations from SpaceX that provide anecdotal information regarding claims that the SpaceX system can meet the Commission's standards for validating sub-100 milliseconds latency and 100 Mbit/s speeds.

SpaceX asserts that a tiny number of best-case measurements show that Starlink can deliver performance that satisfies specific Commission statistical standards for broadband service speed and latency. In reality, good reasons exist to believe that the tiny number of "good" measurements, in the context of a substantially larger number of widely-varying, publicly-available measurements attributed to Starlink beta users, suggests that fundamental issues may exist with Starlink satellites in space that prevent those satellites from ever reliably delivering the required statistical levels of performance.

In the case of SpaceX and its performance claims, anecdotes simply are no substitute for (i) a rigorous methodology that indicates how a fully-loaded network is designed to achieve 100 milliseconds latency and 100 Mbit/s speeds, coupled with (ii) a statistically-valid analysis of measurements of the network actually operating under representative conditions that include boundary cases—including the full range of elevation angles and gateway locations to be employed, and service being provided to a large number of users in the same coverage area.

SpaceX's presentation of anecdotal best-case samples as support for claimed performance suggests that no such analysis has been provided. Moreover, there is no indication that boundary cases are being presented. Indeed, such cases will likely determine whether the Commission's statistically-based tests actually can be satisfied: (i) 95th percentile sub-100 milliseconds latency during peak busy periods, and (ii) 80% of a 100 Mbit/s speed provided 80% of the time during peak busy periods. To be sure, limited numbers of best-case measurements using limited numbers of satellites, a limited number of users, and a lightly-loaded network, will not support a conclusion that those tests can be satisfied.

Thus, the Commission should give little weight to SpaceX's recent assertions regarding the latency and speeds it believes are achievable on its system—including its claims of (i) ping times of 18 milliseconds and 19 milliseconds,[1] (ii) "results from beta initial tests" showing "both low latency below 30 ms and download speeds greater than 100 Mbps,"[2] (iii) "beta testing that confirms speeds above 100 Mbit/s of throughput and latency below 40 ms,"[3] and (iv) "beta testing that confirms latency consistently below 40 ms."[4]

<u>Claimed Speeds of 100 Mbit/s</u>

Good reasons exist to question whether SpaceX can achieve 100 Mbit/s speeds, even with latency levels *above* the Commission's 100 milliseconds "low latency" standard.

As an initial matter, the link parameters provided in SpaceX's license applications would be expected to support data rates far higher than those being reported. That is, speeds of 200-300 Mbit/s would be achievable *if* the satellite payloads actually function consistently with the network design for a given application (in this case, residential service), and the user terminals have the processing power to handle such speeds. Given that SpaceX has asserted the potential for gigabit speeds to individual users with Starlink,[5] it seems somewhat unexpected that user terminals would be limited to 100 Mbit/s by design.

Clearly, the Starlink satellites are not performing to SpaceX design expectations as to reliability and maneuver control, or otherwise as to operating for their entire five-year design lives—some of the few aspects on which the Commission has required information be made

1 *See* Letter of David Goldman, Space Exploration Holdings, LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, Exhibit A, at 5 (filed Sep. 4, 2020) ("*SpaceX Sep. 4 Ex Parte*"); Letter of David Goldman, Space Exploration Holdings, LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, Exhibit A, at 5 (filed Sep. 18, 2020) ("*SpaceX Sep. 18 Ex Parte*").

2 *SpaceX Sep. 4 Ex Parte* at 1; *SpaceX Sep. 18 Ex Parte* at 1.

3 *See* Letter of David Goldman, Space Exploration Holdings, LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, at 1 (filed Sep. 14, 2020).

4 *See* Letter of David Goldman, Space Exploration Holdings, LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, RM-11768, at 1 (filed Sep. 23, 2020).

5 *See, e.g.,* Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016), Narrative, at 2 ("[T]he system will be able to provide high bandwidth (up to 1 Gbps per user), low latency broadband services for consumers and businesses in the U.S. and globally."); *id.* at 5 ("The system will be able to provide broadband service at speeds of up to 1 Gbps per end user.").

public. Actual failure rates reported by SpaceX are well above the 1% figure that SpaceX claimed it would be "nowhere near."[6] Moreover, 35 Starlink satellites have deorbited fewer than 16 months after being launched.[7] It is reasonable to request information on whether other functional measures are similarly far from expectations—and would impair service speeds and the ability to satisfy the Commission's performance metrics. It also is reasonable to request more data than the best-case conditions that SpaceX otherwise uses in its analyses with the Commission.[8] Under these circumstances, any assurances that performance will improve with "iterative designs"[9] would be no comfort at all.

Individual Starlink user terminals will be served by only a single satellite at a time. The amount of time required for a speed test (measured in seconds) is much shorter than the time that a terminal typically will connect to an individual satellite (measured in minutes). Therefore, a majority of speed tests would not involve a handover from one Starlink satellite to another, and thus should be able (if performed in a statistically valid manner and otherwise in accordance with the *Performance Metrics Order*) to provide a reasonable representation of the speed performance of an individual satellite. That most publicly available speed tests still show speeds well below 100 Mbit/s[10] is a troubling sign that the satellites may not be capable of reliably delivering 100 Mbit/s to an individual terminal no matter how few terminals share access to that satellite at any time.

While SpaceX may assert that beta testing is only in the early stages, SpaceX claims to have been communicating with Starlink satellites for over one year.[11] Given that communications were occurring over Starlink last October, it is apparent that SpaceX has had almost a full year to resolve issues with optimizing the speed provided through a single satellite.

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6 *See* Petition to Deny or Defer of Viasat, Inc., IBFS File No. SAT-MOD-20200417-00037, at 26-29 (filed July 13, 2020); Reply of Viasat, Inc. to Opposition of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037, at 15-21 (filed Aug. 7, 2020) ("*Viasat Reply re SpaceX Third Modification*").

7 *See* Letter of Amy Mehlman, Viasat, Inc., to Marlene H. Dortch, Secretary, FCC, IBFS File Nos. SAT-MOD-20200417-00037, SAT-MPL-20200526-00056, at 2-3 (filed Sep. 24, 2020).

8 *See, e.g., Viasat Reply re SpaceX Third Modification* at 4-11 (discussing SpaceX's use of "best case" conditions and varying assumptions to suit the circumstances when assessing collision risk and passive deorbit times).

9 *See, e.g.,* Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, FCC, IBFS File No. SAT-LOA-20161115-00118, at 5-6 (filed April 20, 2017) (SpaceX "will continue to explore new technologies and implement upgrades in an iterative process to ensure that its satellites are highly reliable – a necessity not only for maintaining the continued safety of space, but also for delivering a high-quality service.").

10 *See* TestMy.net, SpaceX Starlink, https://testmy.net/hoststats/spacex_starlink (showing average download speed over four months of 39.6 Mbit/s and maximum daily average download speed of 73 Mbit/s) (last visited Sep. 23, 2020).

11 *See* Don Reisinger, *'Whoa, It Worked!!' Elon Musk Sends a Tweet Through Space Using Starlink, His Developing Satellite Internet Service*, Fortune, Oct. 22, 2019, https://fortune.com/2019/10/22/elon-musk-twitter-spacex-starlink/#:~:text=Elon%20Musk%20tweeted%20from%20space,through%20space%20via%20Starlink%20satellite.%22; Letter from William M. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-LOA-20161115-00118, at 1 (filed July 1, 2019) ("On May 24, 2019, SpaceX launched the first sixty satellites in its Starlink constellation. Fifty-seven Starlink satellites are communicating with SpaceX's earth stations using their broadband phased array antennas.").

Moreover, SpaceX has had many opportunities to iterate on satellite designs and performance. Yet troubling indications exist that a single satellite still is not able to consistently deliver the peak speeds claimed. SpaceX thus may have more to do as it "works through these beta tests."[12] And the issues SpaceX has may be more than a software problem—they may represent a problem with the design, or on-orbit performance, of the satellites themselves.

It is well understood that measured speeds on shared networks (such as satellites) are typically determined in the peak busy periods by provisioning, or oversubscription ratios that further reduce the measured speed available to any individual subscriber on the satellite link based on user demand statistics. Even if Starlink beta tests were to involve hundreds of individuals (based on company statements), SpaceX currently has many hundreds of satellites in orbit. This raises substantial concerns about how scalable the Starlink service is, and how many subscribers it could serve at a given tier of speed service, even with thousands of satellites eventually in operation. This answer can be determined only by detailed analysis and supporting data from on-orbit tests—and certainly not by cherry-picking a tiny number of beta tests and announcing success.

It is highly unlikely that merely increasing the number of Starlink satellites would improve the performance of any individual satellite to a given individual user terminal. Adding more satellites would improve the number of satellites in view at any given point in time, could improve outages due to not having a satellite in view, could reduce the number of subscribers on an individual satellite *when the system is operating at scale*, could improve resilience to satellite failures, or could provide other benefits.

However, having more satellites in view ***would not*** *improve the performance experienced by a very small number of users connecting to an individual satellite at any instance in time—and that issue with connecting to an individual satellite now appears to merit further scrutiny in the context of assessing the ability to reliably achieve consistent 100 Mbit/s speeds in peak busy periods, and at scale.*

Without further information it is difficult to assess through beta tests whether the Starlink satellites currently in space would ever achieve 100 Mbit/s speeds with sufficient reliability. If SpaceX chooses to try to demonstrate satisfaction of the Commission's broadband performance metrics in this manner, the Commission should require thorough, accurate, and definitive analysis—supported by representative and statistically-valid on-orbit measurements—before considering whether Starlink service can satisfy any of those performance metrics.

Claimed Latency Below 100 Milliseconds

As an initial matter, SpaceX's citation to 18-19 milliseconds ping tests is *not representative* of expected round-trip ping times for all subscribers in all geographic locations, under peak busy period network loading, and under all terrestrial network conditions for a LEO system at 550 km. Indeed, approximately *17 milliseconds of free space*

[12] *SpaceX Sep. 4 Ex Parte* at 1.

propagation delay alone exists at 550 km when both gateways and user terminals operate at their lowest specified elevation angles. The satellite propagation component of end-to-end latency at a 25-degree angle is about *2.3 times* more than when operating directly overhead, due to the increased path length at that angle.

For similar reasons to those discussed above with respect to claimed speeds, *best-case* latency measurements, on an extremely-lightly loaded network, without regard to geographic location relative to terrestrial network components, do not support a conclusion about the ability to meet the Commission's 100 milliseconds ping time requirement. That requirement is under peak busy period conditions, for the 95th percentile, and for representative locations, to reflect the ability to generally provide that level of service.

As Viasat has pointed out previously, achieving 100 milliseconds of latency 95% of the time in the peak busy period, for all subscribers, can be challenging for any complex nationwide network—satellite or terrestrial. Best engineering practice requires the development of a thorough latency budget, incorporating all network components, queues, synchronization events, propagation delays, and other factors that can affect latency. Network beta test results, especially those that are clearly "best case possible" measurements, can help confirm many elements of such a budget, but they do not address the potentially very significant effects of peak busy period loading, or geographic location.

Classic queuing theory tells us the relation between offered load and wait times (or latency) as a function of system, or network component, capacity. As illustrated in Figure 1 below, the wait time is small as long as the offered load is well below capacity, but it increases dramatically (as 1/(1-load/capacity)) when the offered load approaches capacity and begins to congest the system.

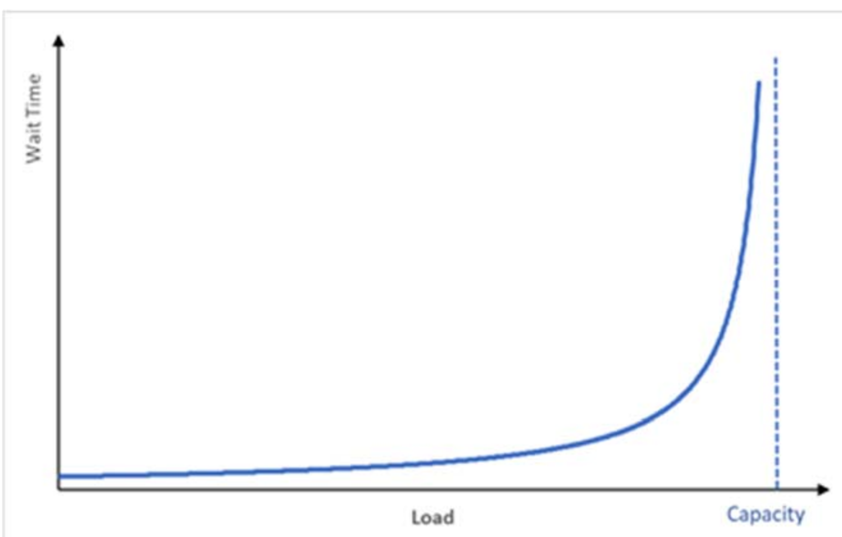

Figure 1: Queuing Delay vs. Load

This figure helps illustrate the peril of relying solely on selected ping testing of any network (LEO or otherwise) with little or no loading to determine whether the network can meet the low-latency requirement in which 95% of the round-trip measurements must be below 100 milliseconds for all measured locations. Such "beta" tests provide no insight into the performance of a LEO network under peak loading conditions, which can differ markedly from the early-phase testing of the network under light loading. Moreover, any of the many elements of system design can greatly exacerbate these congestion-based impacts on latency—including, for instance, any processing, switching, and routing performed *on-board the satellite*, which can introduce potentially significant queueing delays during high congestion. Thus, the only way for a service provider to demonstrate its ability to comply with the low latency requirement is with a detailed element-by-element latency budget considering minimum, maximum, median, and 95th percentile values of latency for every element in the communications path, supported by representative testing under load and across geographic locations. In a terrestrial network, testing under load may surface unanticipated bottlenecks that could be corrected. But, with a satellite network, if bottlenecks surface under loaded conditions *in the satellites already in space*, it is not at all clear that all of the satellites could even possibly be replaced in a timely fashion to meet latency obligations.

Limitations of Beta Testing

The Commission also should be wary of, and should carefully scrutinize, any beta testing measurements. A small sample size of measurements based on cherry-picked numbers is not statistically relevant to demonstrating compliance with the 95th percentile sub-100 millisecond latency requirement or the 80/80 speed requirement, in each case as measured during peak busy periods, and at representative locations. It is well understood that measured speeds and latency on shared networks (such as satellites) can vary depending on system loading, particularly during the peak busy periods. The answer to what speeds and latency levels consistently may be supported can be determined only by detailed analysis and *supporting data from on-orbit tests under representative conditions.*

Moreover, measurements that vary widely from test to test under the relatively uniform conditions of a lightly-loaded beta network with limited geographic diversity may indicate a high variance in the probabilistic components of network performance, and thus an even wider range of possible measurement values in a statistically significant sample set under peak busy period load, and in different geographic locations. This may include (i) values above 100 milliseconds with a frequency greater than 5%, and (ii) speeds below 80 Mbit/s (80% of 100 Mbit/s) with a frequency greater than 20%.

Geographical components to ping test measurements may be significant, as the path lengths between different locations will have a statistical distribution, including due to latency on the terrestrial network from different satellite gateways to a selected Internet Exchange Point (IXP). Many individual users, depending on their geographic location, and the density of subscribers in their surrounding areas, also may be attached to different geographic gateways at different times, or even during the course of a single ping test. Each gateway may connect to an IXP with different propagation and queueing paths and statistics. Notably, publicly available data about SpaceX beta testing addresses results in only two urban centers, Los Angeles and Seattle.[13] Moreover, those two urban locations are hardly representative of SpaceX's claimed target market of "rural America."[14]

The number of users that can access a given satellite in the same service area also may be significant. As noted above, that most publicly-available speed tests still show speeds well below 100 Mbit/s is a troubling sign that the satellites may not be capable of reliably delivering over 100 Mbit/s to an individual terminal no matter how few terminals share access to that satellite at any given time.

Moreover, a high degree of statistical rigor may be necessary to evaluate beta test measurements when small sample sizes exhibit significant variance, and/or occasional values at or near the 100-millisecond requirement or with respect to speeds at or near 100 Mbit/s.

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Based on the information on the public record, there is no reason to conclude that SpaceX consistently can deliver 100 Mbit/s service throughout the United States to residential customers. Moreover, the Commission can and should expect that, if and when SpaceX begins commercially offering something other than a "beta" service, the 95th-percentile measurements of round-trip latency of SpaceX's Starlink network will quite likely be *substantially higher* than the latency times SpaceX claims today. The only issue is exactly how much higher and at what likelihood.

Respectfully submitted,

/s/

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13 *See* Reddit, List of Confirmed Starlink Speed Tests, https://www.reddit.com/r/Starlink/comments/i9w09n/list_of_confirmed_starlink_speed_tests/ (showing list of confirmed Starlink speed tests in Seattle and Los Angeles) (last visited Sep. 24, 2020).

14 *See* Jon Brodkin, *Elon Musk: Starlink Latency Will Be Good Enough for Competitive Gaming*, Ars Technica, Mar. 10, 2020, https://arstechnica.com/information-technology/2020/03/musk-says-starlink-isnt-for-big-cities-wont-be-huge-threat-to-telcos/ ("the SpaceX CEO argued that Starlink won't be a major threat to telcos because the satellite service won't be good enough for high-population areas and will mostly be used by rural customers without access to fast broadband").

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