RS Access, LLC

July 15, 2022

VIA ECFS

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
45 L Street, NE
Washington, DC 20554

Re: Notice of *Ex Parte* Presentation
Expanding Flexible Use of the 12.2-12.7 GHz Band, WT Docket No. 20-443

Dear Ms. Dortch:

RS Access submits an analysis produced by RKF Engineering Solutions, LLC ("RKF") to respond to the June 21, 2022, submission of Space Exploration Technologies Corp. ("Starlink") in this proceeding.[1] In the attached supplemental report, RKF has sought to replicate Starlink's examination of 5G and NGSO systems in the Las Vegas, Nevada market and identify the factors driving the disparity between Starlink's claims and the results of RKF's prior studies.

Because of the opaque and summary nature of Starlink's short filing, RKF had to spend several weeks identifying assumptions implicit in Starlink's submission and reconciling the differences. But—having completed this work—RKF's reconciliation now allows the Commission to review the two sets of assumptions side-by-side and decide which offers the most reasonable, accurate, and complete view of system architectures, service models, and radiofrequency propagation characteristics. For its part, RKF states that its review of the Starlink submission has only strengthened its confidence that 5G deployments will have no effect on at least 99.85% of NGSO operations in the 12 GHz band.

[1] *See* SpaceX, *SpaceX Analysis of the Effect of Terrestrial Mobile Deployment on NGSO FSS Downlink Operations* (June 21, 2022), attached to Letter of David B. Goldman, Senior Director, Satellite Policy, Space Exploration Technologies Corp., to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443, GN Docket No. 17-183 (filed June 21, 2022) ("Starlink June 21, 2022 Submission"); Letter of David B. Goldman, Senior Director, Satellite Policy, Space Exploration Technologies Corp., to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443, GN Docket No. 17-183 (June 23, 2022).

RKF's supplemental report discusses several significantly misleading and unsupportable assumptions used in the Starlink simulation and the relative impact of those assumptions on the final results it has advertised to the Commission and the public. Starlink's implausible assumptions explain the overwhelming majority of the difference between the 0.15% exceedance calculated by RKF and the 77.5% exceedance alleged by Starlink. The more egregious of those assumptions include the following:

Exceptionally narrow geographic scope: Starlink's study considered interference in a single, cherry-picked partial economic area ("PEA") rather than conducting a nationwide modeling analysis as RKF took the time and effort to do. The Las Vegas PEA, however, is not at all a typical interference environment and is in many ways an extreme outlier; due to its unique topology, morphology, and population distribution, Las Vegas is especially inhospitable to radio coexistence. Starlink ignores 405 of the 406 PEAs in the contiguous United States to manufacture its desired result.

Unsupportable terminal distribution and deployment assumptions: Starlink's modeled deployment in Las Vegas placed an unsustainable 54 percent of Starlink user terminals in urban and suburban areas.[2] Starlink and Elon Musk have frequently conceded that the architecture of NGSO systems imposes physical limits on the system's ability to serve more than a trivial number of subscribers in high-density urban areas.[3] Starlink's own recent filing implies as much through the use of a hypothesized deployment of just 1,000 user terminals in the *entire* Las Vegas PEA. Starlink remains silent on why it contemplated only 1,000 user terminals in its submission, but given the resulting density of its hypothesized subscriber base, Starlink likely needed a low limit on the number of user terminals in Las Vegas to avoid exceeding the limits inherent in the NGSO system's capacity. In any case, Starlink simply cannot apply the terminal distribution it conjures for Las Vegas to a national market, nor can it meaningfully increase the number of customers within the Las Vegas market without exceeding the capacity of its NGSO system.

Irrational channel limits: Starlink ignored the fact that Starlink terminals can operate outside the 12.2-12.7 GHz band. Starlink's effective neglect of the other 1,500 megahertz of Ku-band downlink spectrum licensed for its use seems particularly odd given that Starlink's authorizations at 12.2-12.7 GHz remain conditioned on the outcome of this proceeding[4] and that its application

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[2] *See* Starlink June 21, 2022 Submission at 9.

[3] *See, e.g.*, Elon Musk (@elonmusk), Twitter (May 4, 2021, 5:22 PM), https://bit.ly/3tmjtwz ("[The o]nly limitation [for Starlink] is high density of users in urban areas."); *see also* Jon Brodkin, *Elon Musk: Starlink Latency Will be Good Enough for Competitive Gaming*, ARS TECHNICA (Mar. 10, 2020), https://bit.ly/3d Urbbu ("The challenge for anything that is space-based is that the size of the cell is gigantic … it's not good for high-density situations. … We'll have some small number of customers in LA. But we can't do a lot of customers in LA because the bandwidth per cell is simply not high enough." (first ellipsis in original)), CNET Highlights, WATCH: Elon Musk discuss Starlink Internet at MWC 2021 - Livestream, YouTube, at 4:14-41 (June 29, 2021), https://youtu.be/RcnVTgrgThE (Stating Starlink can serve "a limited number of customers" in "high density areas.").

[4] *See, e.g., Space Exploration Holdings, LLC, Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Order and Authorization and Order on Reconsideration, IBFS File No. SAT-MOD-20200417-00037, 36 FCC Rcd 7995 ¶ 50 (2021); *Space Exploration Holdings, LLC, Application for Approval*

for Rural Digital Opportunity Fund ("RDOF") subsidies is premised on access to the full Ku-band downlink assignment.[5]

Unrealistic distribution of user terminal heights: Starlink's study assumed 90% of Starlink subscribers would self-install user terminals at 4.5 meters above ground level, where they are more susceptible to interference. This goalpost-shifting assertion represents just the latest iteration of an implausible and unsupported claim that flies in the face of Starlink's market guidance, advertising material, no-truck-roll business model, and Starlink's very own installation advice to its consumers.[6]

Unprecedented 5G base station deployments: To inflate 5G/NGSO interference, Starlink assumed a number of 5G base stations that is obviously wrong—far exceeding any current or future cellular network build-out[7] and demonstrating the company's lack of even a basic understanding of 5G network deployments. Indeed, if one were to scale the Las Vegas tower density model Starlink used to a national level, Starlink's model would require a terrestrial operator to deploy up to 610,000 5G macrocells to achieve nationwide coverage. By comparison, one of the nation's largest mobile wireless service providers, AT&T, reported having deployed only 75,000 base stations[8] to support its nationwide mobile network that today serves at least 100,000,000 subscribers[9] and relies on a spectrum portfolio that spans frequencies ranging from the 700 MHz to the 24 GHz band.

Correcting just a handful of the results-driven assumptions in Starlink's submission—namely, the narrow geographic scope, the unsupportable terminal distribution, and the irrational channel limits—entirely deflates Starlink's claims about the potential for exceedance in the 12 GHz band.

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for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System, Memorandum Opinion, Order and Authorization, IBFS File No. SAT-LOA-20161115-00118, 33 FCC Rcd 3391, 3407 ¶ 40(r) (2018).

[5] In Starlink's application for subsidies through the Commission's Rural Digital Opportunity Fund ("RDOF"), Starlink insisted it would rely on the full 2,000 megahertz of its Ku-band assignment. *See* Space Exploration Technologies Corp., SpaceX Form 183, Spectrum Access Attachment; *see also* Space Exploration Technologies Corp., State & Tier Eligibility, Auction 904-0009149922 (filed Oct. 23, 2020) (indicating Starlink has access to 2,000 MHz of downlink Ku-band spectrum in every state).

[6] After Starlink insisted that an unspecified "majority" of NGSO FSS terminals would rely on rooftop installation, RKF adjusted the assumption of 20% roof-mounted terminals that appeared in its 2021 coexistence analysis to a 55% majority of all Starlink user terminals in its 2022 coexistence analysis. *See, e.g.*, 2022 RKF Study at 21 ("Although RKF finds these assertions to be unsupported and inconsistent with publicly available information about Starlink terminal deployment practices by consumers, RKF now assumes, out of an abundance of caution, that a majority (55%) of terminals will have a 4.5m HAGL [height above ground level] consistent with rooftop installation.").

[7] As RKF explains in the attached report, scaling Starlink's Las Vegas deployment of 3,215 base stations on a POPs per base station basis would require an operator to deploy some 610,000 macrocell base stations to ensure nationwide coverage.

[8] *See* Mike Robuck, *AT&T Turns Up AI for Drones, Load Balancing, 5G Build Out*, Fierce Telecom (Sept. 26, 2019) https://www.fiercetelecom.com/telecom/at-t-turns-up-ai-for-drones-load-balancing-and-5g-build-out.

[9] AT&T's latest quarterly earnings reported nearly 200,000,000 subscribers in its mobility unit. *See* AT&T Inc., Quarterly Report (Form 10-Q) (Mar. 31, 2022) at 37.

Applying realistic values for just these three factors causes Starlink's exceedance claim for the Las Vegas PEA to plummet from 77.5% to 0.3%, or just *three* hypothetical subscribers of the one thousand Starlink considers in the market, a level at which 5G/NGSO coexistence is readily feasible.

* * *

RS Access urges the Commission to act swiftly to authorize 5G operations in the 12.2-12.7 GHz band. The 12 GHz band is well suited for 5G operations, and deploying 5G in the 12 GHz band would deliver meaningful economic and public interest benefits to American consumers without affecting future NGSO services.

Sincerely,

/s/ V. Noah Campbell

V. Noah Campbell
CEO
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Attachment

Analysis of Starlink Submission Regarding the Effect of 5G Deployment on NGSO FSS

July 15, 2022

RKF Engineering Solutions, LLC ("RKF") submits this supplemental report in response to a recent technical submission from Space Exploration Holdings, LLC ("Starlink").[1] RKF has prepared two highly detailed engineering studies for use in this proceeding[2] that confirm opening the 12.2-12.7 GHz band for 5G deployment poses an extremely low risk of harmful interference with non-geostationary satellite orbit ("NGSO") fixed-satellite service ("FSS") operations authorized to operate in the 10.7-12.7 GHz band on a co-primary basis with terrestrial mobile broadband services.[3] In response to RKF's technical studies, Starlink appears to have mischaracterized RKF's methodology, misrepresented crucial facts, and generally obfuscated the issues at hand.

Despite its new form, Starlink's June 22, 2022 submission is more of the same. RKF completed a painstaking exercise to fully review Starlink's claims. This detailed examination reveals that the Starlink contentions are misplaced. Further, it reinforces RKF's confidence in the viability for co-existence of 5G services at the 12 GHz band because the interference potential is almost non-existent at an exceedance rate of 0.15%, meaning 99.85% of Starlink users have no probability of exceedance, as demonstrated in RKF's 2022 Monte Carlo analysis. Specifically, Starlink's submission alters assumptions in RKF's nationwide Monte Carlo analysis, eliminates every market except for the Las Vegas Partial Economic Area ("PEA"), and purports to find that opening the 12 GHz band to 5G terrestrial broadband services would produce an exceedance rate for NGSO

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[1] *See* Space Exploration Holdings, LLC, *SpaceX Analysis of the Effect of Terrestrial Mobile Deployment on NGSO FSS Downlink Operations* ("Starlink June 21, 2022 Submission"), attached to Letter from David Goldman, Senior Director, Satellite Policy, SpaceX, to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443, GN Docket No. 17-183 (June 21, 2022) ("Starlink June 21, 2022 Letter").

[2] *See* RKF Engineering Solutions, LLC, *Assessment of Feasibility of Coexistence between NGSO FSS Earth Stations and 5G Operations in the 12.2 – 12.7 GHz Band* (May 2021) ("2021 RKF Study"), attached to Comments of RS Access, LLC, WT Docket No. 20-443 (May 7, 2021) ("RS Access, May 7, 2021 Comments"); RKF Engineering Solutions, LLC, *The Effect of 5G Deployment on NGSO FSS Downlink Operations in the 12.2-12.7 GHz Band* (May 18, 2022) ("2022 RKF Study"), attached to Letter from V. Noah Campbell, CEO, RS Access, to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443 (May 19, 2022) ("RS Access, May 19, 2022 Letter").

[3] *See* RS Access, May 19, 2022 Letter at 2-3 ("Despite the use of technical parameters advanced by Starlink that are uniformly weighted against coexistence, RKF's Monte Carlo simulation f[ound] that 99.85% of NGSO terminals deployed over contiguous United States do not even experience a technical 'exceedance event' in the 12 GHz part of the 2,000 megahertz of Ku-band downlink spectrum they can use." And "even for the 0.15% of Starlink terminals identified as experiencing an exceedance event in the 12 GHz portion of the Ku-band downlink, service would not be affected unless the exceedance event both rose to a level of actual harmful interference and all other 250-megahertz channels assigned to NGSO licensees in the 10.7-12.7 GHz band were simultaneously unavailable").

terminals of 77.5 percent. If true, this figure would represent a more than 500-fold increase of the 0.15 percent exceedance rate that RKF identified in its 2022 Monte Carlo analysis.[4]

What accounts for such a large discrepancy?

To answer this question, RKF sought to replicate Starlink's examination of 5G and NGSO systems in the Las Vegas, Nevada market and identify the core assumptions that could cause such a radical discrepancy from the results of RKF's May 2021 and May 2022 studies. In its submission, Starlink failed to offer an accounting of the incongruity between its claims and the RKF findings; therefore, RKF has spent the last several weeks reconciling the differences. This supplemental report provides a reconciliation between the RKF analysis and the Starlink submission in the hope that a straightforward presentation will allow the Commission to review the two sets of assumptions and decide which offers the most reasonable, accurate, and complete view of the system architectures, service models, and radio-frequency propagation characteristics of real-world deployments in the 12.2-12.7 GHz band.[5]

I. Starlink's "Technical Study" Presents Implausible Results, Driven by Unrealistic Assumptions.

RKF examined Starlink's approach to try to understand the assumptions behind the exceedance that Starlink has presented to the Commission.[6] This was not a simple task as the SpaceX submission is short, providing few specific technical details. While the lack of transparency complicated the work, RKF extracted a set of core assumptions from Starlink's narrative. RKF then introduced the changed assumptions one at a time into its analysis and, following the introduction of each, calculated the exceedance level that resulted from the change when combined with the remaining unmodified assumptions of the RKF study. Through a painstaking process that required new runs of the model following each modification, RKF identified seven factors that drive most of the difference in exceedance rates.

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[4] *See* Starlink June 22, 2022 Letter. The increase is arrived at by dividing the 77.5% exceedance claimed by Starlink by the 0.15% exceedance calculated by RKF.

[5] Starlink's submission and cover letter contain claims not germane to a technical analysis. This supplementary technical report does not address Starlink's sundry legal contentions, nor does it address the various modeling assumptions, such as line-of-sight probabilities, that Starlink questions but for which it does not propose an alternative.

[6] An "exceedance event" occurs when an incumbent terminal receives a radio emission that surpasses a nominal threshold established by governing bodies in radio engineering. In its studies, RKF has used an exceedance threshold of -8.5 dB I/N defined by the International Telecommunication Union. Starlink has encouraged the use of a lower threshold of -12.2 dB I/N. *See* Letter from David Goldman, Director of Satellite Policy, Space Exploration Technologies Corp., to Marlene H. Dortch, Secretary, FCC, WT Docket No. 20-443 and GN Docket No. 17-183, at 6 (filed Feb. 3, 2022). There is little sound basis for Starlink's preferred threshold. But as RKF has explained and reiterates below, use of the lower threshold would not materially affect RKF's findings because a -12.2 dB I/N increases the noise level by only 0.3 dB relative to -8.5 dB I/N.

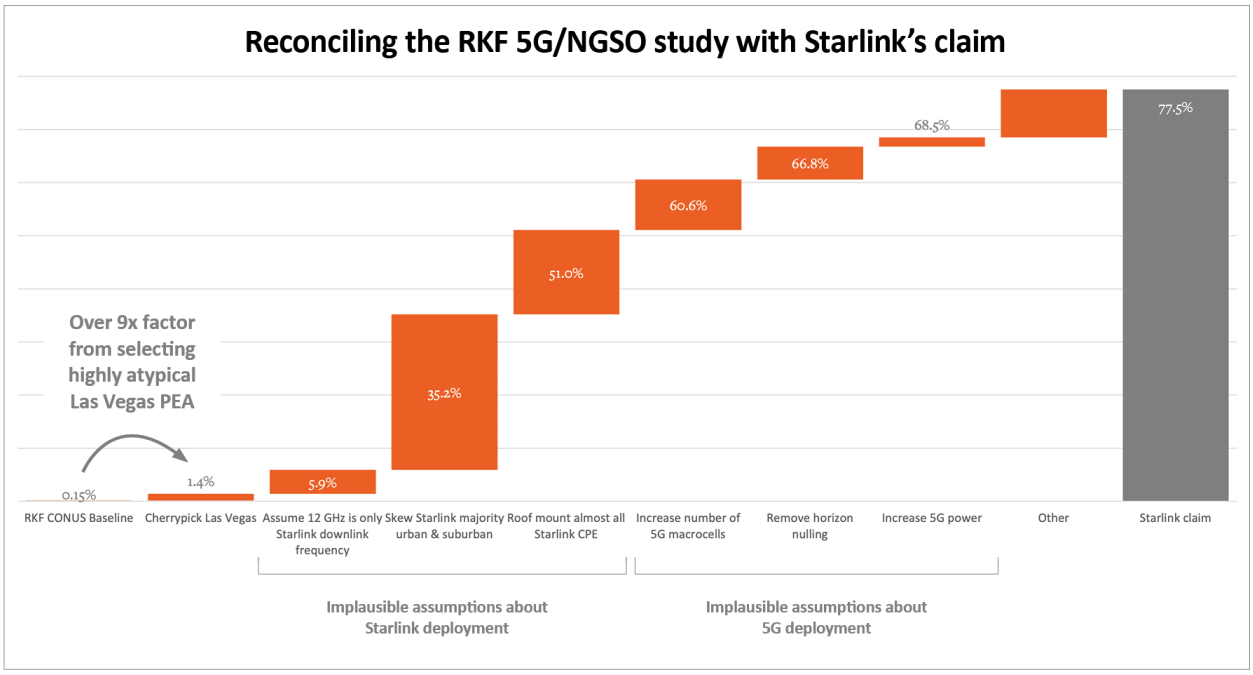

Figure 1: The main drivers of difference between RKF's study and Starlink's claim expressed as percentages of the discrepancy between RKF's study and Starlink's claim.

As shown in the image above, Starlink inflated the exceedance value found by RKF by seven methods, none of which is valid, and all of which together take RKF's prior finding of near-zero interference potential and cumulatively multiply it by more than 500-times. The changes that most inflated the exceedance value identified by RKF were as follows: (1) selecting the Las Vegas PEA in lieu of a nationwide study; (2) disregarding the availability of NGSO downlink spectrum outside of the 12.2-12.7 GHz band; (3) placing 54% of Starlink deployments in urban and suburban environments, contrary to Starlink's nationwide capabilities and business model; (4) roof mounting an unrealistic 90% of user terminals at 4.5-meter elevation, a height at which they would be more susceptible to interference; (5) increasing the number of 5G macrocells to a level that, on a nationwide basis, would far exceed any real-world deployment; (6) ignoring 5G advanced antenna system ("AAS") capabilities available in beamforming chipsets today for performing horizon nulling or sidelobe suppression; and (7) increasing 5G effective isotropic radiated power ("EIRP") beyond average levels used in 5G deployments.[7]

A related means of presenting the effect of Starlink's questionable assumptions is to show the multiplier effect that each of Starlink's changed assumptions has on the 0.15 percent exceedance RKF identified. Working from the same sequence of changes shown in Figure 1 above, Figure 2

[7] Emulating the combination of Starlink's flawed assumptions allowed RKF to account for exceedance values of 68.5%. The remaining percentage of exceedance (labeled "Other" in the diagram above) appears to be comprised of small factors that do not contribute materially on an individual basis as well as other as-yet undisclosed alterations not identified by Starlink. One of several known unwarranted contributing factors, for example, is Starlink's use of a -12.2 dB I/N exceedance threshold rather than the ITU's -8.5 dB I/N threshold.

shows how Starlink's choice of the atypical Las Vegas PEA drove an exceedance value *nine times* greater than RKF's national average. Skewing Starlink deployments to urban/suburban locations from rural areas produced a further nearly *six-fold* increase. And assessing interference across only the 12.2-12.7 GHz band instead of the full, 2,000 megahertz Ku-band NGSO allocation licensed to Starlink for downlink use multiplied exceedance by an additional *four times*. Other factors shown below also caused misleading and multiplicative changes, and together they allow for a reconciliation between RKF's results and Starlink's claim. ***For example, just applying the three largest multipliers shown in Figure 2 would reduce Starlink's claim from 77.5% to 0.3%, which equates to exceedance affecting just three hypothetical subscribers of the one-thousand modeled by Starlink.***[8]

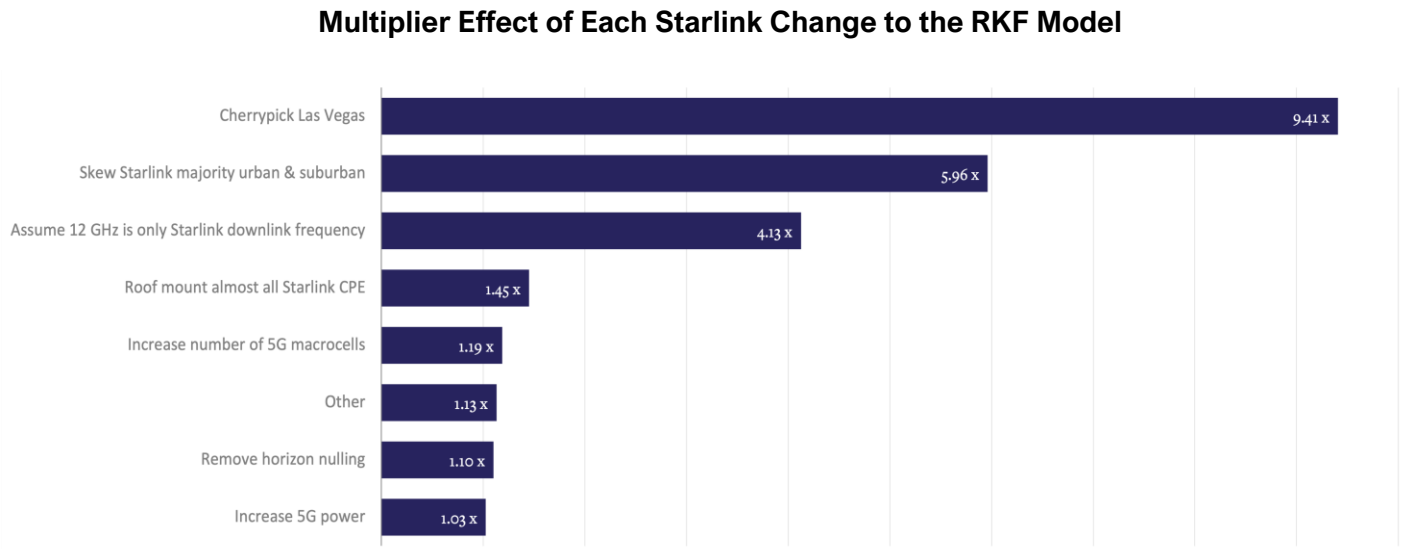

Figure 2: The main drivers of the difference between RKF's study and Starlink's claim expressed as multipliers to illustrate each factor's relative distortive effect.

II. How Starlink's Unrealistic Assumptions Drive Its Inflated Exceedance Claim.

Starlink's review of RKF's work rests on three categories of flawed assumptions. Broadly defined, the principal categories of error involve an artificially narrow scope; unrealistic Starlink network assumptions; and incorrect 5G network assumptions.

Artificially Narrow Scope. Starlink started its effort by shrinking the geographic study area from RKF's national scope to a review of just one PEA with terrain and population features that deviate markedly from the types of conditions found in virtually every other PEA in the United States. In other words, Starlink eliminated 405 of the 406 PEAs in the contiguous United States ("CONUS") as though they were irrelevant to the analysis. Further, Starlink then proceeded to effectively disregard all its downlink spectrum apart from the 500 megahertz available in the 12.2-12.7 GHz band.

[8] The reduction is attributable to a combination of the multiplier effects of the factors above, namely 9.41 x 5.96 x 4.13, which equals a 231-fold reduction.

Unrealistic Starlink Assumptions. After having cherry-picked an anomalous geographic study area and an effective frequency baseline 25% the size of RKF's model, Starlink then proceeded to alter a series of input assumptions used in the RKF analysis. Starlink stated it used "actual user demand" to model the distribution of a "representative" 1,000 NGSO user terminals, placing 17% in urban areas, 37% in suburban areas, and 46% in rural areas.[9] Starlink also referenced an unspecified customer survey to support its assertion that 90% of Starlink user terminals would be mounted on rooftops where the receivers are more susceptible to emissions.[10]

Incorrect 5G Assumptions. Based in part on the incorrect assertion that RKF's model covered only 10% of the population of CONUS and only 10% of the population in any given PEA,[11] Starlink "scaled" the 5G terrestrial coverage to 70% of the PEA's population, which required siting 3,215 macrocell base stations in the Las Vegas PEA.[12] Although RKF was very clear that its 5G macrocell model positioned base stations in the most densely populated tracts of each PEA, Starlink declined to explain how the area corresponding to 70% of the population was selected. Starlink generally asserted it had positioned 5G macrocell base stations and user terminals in urban, then suburban, then rural environments according to the model that RKF used when, in fact, the distribution appears not to have followed RKF's model. For example, RKF noted that it used version 4.11 of the 2020 Gridded Population of the World ("GPW") population-density database "to determine the morphology classification of the local area so that the appropriate site spacing could be applied,"[13] yet Starlink's study does not mention using GPW data at all. The upshot is that while RKF explained the critical factor of the methodology it used to site 5G macrocells in detail, Starlink's approach remains entirely undefined and results in an obviously overstated number of macrocells.

III. Seven Unrealistic Assumptions Drive the Vast Majority of Starlink's Inflated Exceedance Claim.

Each incorrect assumption underpinning Starlink's analysis contributes to the discrepancy between RKF's nationwide engineering analysis and SpaceX's Las Vegas-only submission. Below, RKF discusses each of the seven major drivers in more detail.

First, Starlink selected a single partial economic area, Las Vegas, Nevada, for its analysis rather than conducting a nationwide study. The 406 PEAs across CONUS vary in topology, morphology, population distribution, and other factors important to an assessment of coexistence

[9] Starlink June 21, 2022 Submission at 9, 15.

[10] *Id.* at 8.

[11] As stated in the first RKF report, "census tracts with population density greater than 7,500 people per square mile roughly match the dense urban portions of many cities, so the model uses that figure as a threshold and ensures that these areas were included as areas where 12 GHz was likely to be deployed." In Las Vegas, tracts with a 2010 population density of 7,500 POPs per square mile or more comprise 33.3% of the PEA's population. Thus, RKF's model covered 33.3% of the population of the PEA, not 10% as Starlink irresponsibly claimed. RKF's analysis to determine the 5G coverage areas used the 2010 Census, because the first RKF report preceded the release of the 2020 Census.

[12] *Id.* at 15.

[13] 2021 RKF Study at 29-30.

among radiofrequency technologies. In addition, the housing pressures have typically resulted in most PEAs realizing greater population density either through a densifying urban core, or through sprawling development, or both.

In contrast, the Las Vegas valley is essentially flat with low-rise buildings throughout much of the area, and the vast bulk of the PEA population is neither located in a dense urban core, nor spread across a suburban sprawl of homes separated by expansive lots, but rather confined to a large desert oasis of medium-density housing surrounded by vast expanses of largely barren land. Although there are broad rural tracts within the PEA, the population concentrated in urban and suburban areas exceeds the average population density of that found in PEAs covering the rest of CONUS. The unusual, if not unique, layout of the Las Vegas PEA, results in this PEA exceeding the national average rate of exceedance by more than nine times the national average RKF identified in its analysis.

Las Vegas is not representative of the radiofrequency environment or the population distribution of the average PEA in the nation. Nevertheless, Starlink's analysis rests on that hand-picked PEA and encourages the Commission to treat Las Vegas as the foundation for nationwide policy. In contrast, the RKF studies appropriately provided the required comprehensive nationwide analysis.

Second, Starlink effectively ignored its Ku-band downlink channels outside the 12.2-12.7 GHz band. RKF's simulation randomly assigned Starlink user terminals to one of the eight channels to which Starlink has access. Starlink, by comparison, measured exceedance in NGSO FSS user terminals either by focusing only on the 500 megahertz of 12 GHz spectrum where coexistence would occur, or by performing a cumulative set of runs across the small pool of terminals in its study so that their submission effectively reaches the same result. Simply accounting for Starlink's ability to use the other 1,500 megahertz of Ku-band downlink capacity in its spectrum assignment at any given point in time reduces Starlink's ostensible exceedance value by a factor of four.[14]

The basis for ignoring the other 1,500 megahertz available for Starlink's use remains unclear. In its latest submission, Starlink at one point appears to concede the utility of all but the lowermost 250 megahertz of its spectrum. The company says "the SpaceX analysis is based on seven 240 MHz channels with 250 MHz spacing from 10.95-12.7 GHz" even as it proceeds to disparage the value of any band segment other than 12.2-12.7 GHz for NGSO use.[15] Other parties to this proceeding have addressed Starlink's arguments about the purported limits on the 10.7-12.2 GHz band segment before, and RKF will not revisit them here.[16] For present purposes, it is sufficient to

[14] If Starlink's claim about the unavailability of the lowermost 250 megahertz of its allocation is credited as true, notwithstanding the company's representation about how it intends to rely on that same spectrum to satisfy the performance criteria needed to win government Rural Digital Opportunity Fund subsidies, then accounting for the remaining 1,750 megahertz of spectrum would still reduce the exceedance value by 71.4% instead of 75.0%. *Cf., e.g.*, Space Exploration Technologies Corp., File No. 0009149922, Form 183, Spectrum Access Attachment at 2 (Oct. 23, 2020) ("detail[ing] the link, transmission direction, and frequency ranges that SpaceX will use for [RDOF] supported services" to support user downlink operations as "10.7 – 12.7 GHz").

[15] Starlink June 21, 2022 Submission at 9.

[16] *See, e.g.*, RS Access, May 19, 2022 Letter at 9-10.

note that Starlink continues to shrug off the value and utility of any band segment other than the 12.2-12.7 GHz band, even though—when it sought government subsidies for deployment through the Commission's Rural Digital Opportunity Fund ("RDOF")—Starlink insisted it would rely on the full 2,000 megahertz of its Ku-band assignment.[17] Starlink's representations about useful bandwidth in this proceeding contradict its representations about the same matter in its application for RDOF subsidies. Either 2,000 megahertz of spectrum are available for Starlink's use, or they are not.

In addition, the Commission has repeatedly and consistently conditioned grants of 12 GHz NGSO FSS authority on the outcome of the 12 GHz flexible-use proceeding. NGSO FSS licensees, investors, and the public received more than sufficient warning that NGSO licensees must proceed at their own risk. The Commission recently reminded NGSO operators that the agency may seek to expand the terrestrial capabilities available in the 12 GHz band when it granted SpaceX's third modification application.[18] Thus, neither the existence of terrestrial licenses, nor the potential for a long-overdue modernization of the service rules governing the band, should come as a surprise to any NGSO operator who has responsibly planned their network designs.

Third, Starlink's submission places 54 percent of the company's user terminals in urban and suburban areas, contrary to its system capabilities and business model. Flipping its satellite service from a rural-focused service into an urban/suburban-focused one not only contradicts years of statements from Starlink and Elon Musk to the Commission, Starlink's own customers and the general public, but also implies the new satellite entrant will meaningfully penetrate markets in which fiber, hybrid-fiber coax, and terrestrial wireless broadband providers already offer services that perform better and cost less than Starlink's offers.

But Starlink's new-found interest in serving densely populated areas must confront a much more fundamental, *physical* problem owing to the basic architecture of NGSO satellite design: Starlink can either have a large number of customers, or a large percentage of its customers in densely populated areas. It cannot have both. In other words, technical limitations of Starlink's satellite system make it physically impossible to serve a large percentage of customers in densely populated areas after surpassing a very low threshold of total subscribers.[19]

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[17] *See* Space Exploration Technologies Corp., SpaceX Form 183, Spectrum Access Attachment. In the company's State and Tier Eligibility filing, Starlink further indicated access to 2,000 MHz of downlink Ku-band spectrum in every state, including those where Radio Astronomy observatories are located. *See* Space Exploration Technologies Corp., State & Tier Eligibility, Auction 904-0009149922 (filed Oct. 23, 2020).

[18] *See, e.g.*, *Space Exploration Holdings, LLC, Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Order and Authorization and Order on Reconsideration, IBFS File No. SAT-MOD-20200417-00037, 36 FCC Rcd 7995 ¶ 50 (2021); *Space Exploration Holdings, LLC, Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, Memorandum Opinion, Order and Authorization, IBFS File No. SAT-LOA-20161115-00118, 33 FCC Rcd 3391, 3407 ¶ 40r (2018).

[19] *See, e.g.*, Letter from David Marshack, Managing Director and Chief Operating Officer, RKF Engineering Solutions, LLC, to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443 at 3-4 & n.13 (Aug. 9, 2021), *citing* CNET Highlights, WATCH: Elon Musk discuss Starlink Internet at MWC 2021 - Livestream, YouTube, at 4:34-39 (June 29, 2021), https://youtu.be/RcnVTgrgThE; *see also* Elon Musk

The physical capacity limits of an NGSO system are critically important to understanding why Starlink's assumption about an ostensibly urban-oriented satellite service is so deeply flawed. These limits also likely explain why Starlink's submission slashed the number of terminals it models in Las Vegas to just 1,000 from RKF's much more generous number of 5,882 user terminals despite complaining that RKF's subscriber count was too *low*.

As a threshold matter, Starlink continues to dismiss RKF's methodology for NGSO terminal siting and claims RKF should have modeled deployment of millions more Starlink user terminals in dense, urban areas, without providing evidence such deployment is feasible or realistic.[20] Starlink offers opaque references to "orders" or "pre-orders," that indicate hypothetical demand for NGSO services will quickly exceed RKF's modeled assumption of 2.5 million nationwide terminals.[21] The record is then replete with Starlink's strenuous but non-specific objections to RKF's methodology, including claims that RKF used "lowball" or "extremely unrealistic and low" figures in its analyses, and accusations that RKF did so with ill-intent.

But in its own study, Starlink declined to analyze a hypothetical, multi-million terminal deployment, or even a deployment in Las Vegas that scales to a nationwide number of subscribers that is even close to RKF's assumption of 2.5 million Starlink terminals and Starlink's own ostensible aspirations for its service. For example, RKF's siting algorithm modeled 5,882 NGSO terminals in the Las Vegas PEA.[22] Although Starlink's underlying methodology remains unclear,[23] Starlink claims to have used a distribution based on some unspecified measure of "actual demand

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(@elonmusk), Twitter (May 4, 2021, 5:22 PM), https://bit.ly/3tmjtwz ("[The o]nly limitation [for Starlink] is high density of users in urban areas."); Jon Brodkin, *Elon Musk: Starlink Latency will be Good Enough for Competitive Gaming*, ARS TECHNICA (Mar. 10, 2020), https://bit.ly/3dUrbbu ("The challenge for anything that is space-based is that the size of the cell is gigantic … it's not good for high-density situations." "We'll have some small number of customers in LA. But we can't do a lot of customers in LA because the bandwidth per cell is simply not high enough.").

[20] *See* Reply Comments of Space Exploration Holdings, LLC at 6, WT Docket No. 20-443, GN Docket No. 17-183 (July 7, 2021) ("Starlink Reply Comments") (stating, without citation, that Starlink will serve "millions of Americans," and that RKF's assumption of 2.5 million Starlink terminals is "extremely unrealistic and low."); *see also* Letter from David Goldman, Director, Satellite Policy, Space Exploration Technologies Corp., to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443, at 5 (Sept. 27, 2021) ("Starlink Sept. 27, 2021 Letter") (criticizing RKF's assumption of 2.5 million Starlink terminals in light of Starlink's pending application to deploy "up to five million terminals.").

[21] Starlink Reply Comments at 6; *see also id.* at iii; *Cf.* Letter from V. Noah Campbell, CEO, RS Access, LLC, to Marlene H. Dortch, Secretary, FCC, WT Docket No. 20-443, at 2-3 (Sept. 14, 2021) ("It appears that what SpaceX represented to the Commission as 'orders' and 'pre-orders' for Starlink service are, in fact, fully refundable $99 deposits that do not obligate the consumer to purchase anything or subscribe to any Starlink service, nor even for Starlink to provide any service at all.").

[22] *See* 2022 RKF Study.

[23] Starlink declines to specify how the population was distributed within the delineated urban, suburban, and rural areas, and it remains unclear whether this distribution was remotely realistic. There are unlimited possible distributions, and several ways by which Starlink could distribute users within a tract that would create an unrealistic or exaggerated risk of interference.

in the Las Vegas market to deploy a representative 1,000 Starlink user terminals."[24] This models a deployment of approximately one terminal to every 2,479 people in the Las Vegas PEA, which scales to a nationwide deployment of approximately 130,000 *total* Starlink terminals across the United States.[25] Scaling it another way, Starlink assumed about one-sixth the number of NGSO terminals in the Las Vegas PEA as RKF, and therefore nationwide this would scale to one sixth of 2.5 million, or about 400,000 subscribers. Regardless of the method used to scale the 1,000 Las Vegas subscribers, the nationwide result completely contradicts Starlink's repeated advocacy that RKF has underestimated the total number of NGSO subscribers in CONUS. Scaling Starlink's Las Vegas model to the national level exemplifies the pretzel-twisting logic behind many of the changed assumptions in Starlink's technical submission.

Equally concerning is that Starlink claims to have used a distribution based on some unspecified measure of "actual demand in the Las Vegas market to deploy a representative 1,000 Starlink user terminals."[26] Does this mean that Starlink has had demand from exactly 1,000 households in the Las Vegas PEA? If Starlink has had demand from more than 1,000 households in the PEA, which 1,000 did it choose? If Starlink has had demand from fewer than 1,000 households, where did Starlink add the additional hypothetical demand for purposes of its submission? RKF does not necessarily contest Starlink's claim that the terminal locations and distribution used were "based on actual demand," but merely observes that there are numerous ways to alter the data to derive terminal locations that are most favorable to Starlink's desired outcome.[27]

[24] Starlink June 21, 2022 Submission at 9; *see also id.* at 3.

[25] The scaling used to establish the total number of Starlink user terminals nationwide using the Las Vegas approach advanced by Starlink is shown in the following table:

Starlink Las Vegas Terminal Distribution Scaled Nationally	
2020 population of PEA026, Las Vegas	2,478,728
Number of Starlink Terminals assumed by Starlink	1,000
2020 POPs per Starlink User Terminal:	2,479
2020 CONUS population	329,260,619
Total Inferred Starlink User Terminals in CONUS	329,260,619 / 2479 = **132,820**

[26] SpaceX June 22, 2022 Study, Attachment at 9; *see also* Attachment at 3 ("SpaceX has provided service to users in Las Vegas, meaning SpaceX is able to model a deployment of its own user terminals based on actual demand for the Starlink service.").

[27] The susceptibility of data to mismanagement applies with equal force to other elements of Starlink's submission, including the -12.2 dB I/N exceedance threshold values that Starlink said it calculated for an alternate distribution of 1,000 terminals in Las Vegas that Starlink claimed was the "same [] pattern as RKF." As part of its exceedance claims, Starlink briefly provided the results of this alternate scenario compared to the results of their "actual demand" terminal distribution and asserted that 64% of terminals would exceed -12.2 dB I/N using RKF's terminal distribution method. Starlink provided no information about how it applied RKF's distribution and offered no guidance about where any of the terminals were located or how their locations were determined. However, one thing is certain: Starlink's interpretation of

Simply put, Starlink is implicitly acknowledging a more fundamental limitation on the potential for exceedance events in the 12 GHz band: NGSO operators lack the per beam capacity to support the high density of user terminals required to support widespread deployment in populous, urban and suburban areas.

Fourth, Starlink models an entirely unprecedented and implausible deployment of 5G macro base stations. In prior filings criticizing RKF's analyses, Starlink mistakenly claims that RKF's 5G deployment model "covers only 10% of each license area."[28] But as others have already explained, this claim is incorrect: RKF's studies model broad deployment covering approximately 20% of the CONUS population, 10% being the *minimum* population coverage target. Many markets, including the Las Vegas PEA, exceed the average and, indeed, RKF's model envisioned covering more than 33% of POPs in the Las Vegas market.[29]

Starlink's study models an implausible deployment of 5G base stations, well in excess of any feasible build-out. RKF's methodology sited 595 macro base stations in the Las Vegas PEA, modeling a 5G network reaching 33.3% of POPs. Starlink modeled an extremely dense 5G network buildout, siting 3,215 base stations to reach 70% of POPs in the same PEA.[30]

Starlink's siting and deployment model is entirely unrealistic. If a 5G operator sought to meet Starlink's assumptions and built-out a nationwide 5G network that scaled the 540 POPs per cell Starlink modeled, the operator would have to deploy 610,000 base stations.[31] By contrast, AT&T

RKF's more rural distribution does not match their purported "actual demand" distribution, so Starlink could not have reasonably based their "RKF distribution" on "actual demand."

[28] *See* Starlink Reply Comments at 14.

[29] In both RKF studies, the siting methodology modeled 12 GHz mobile coverage well beyond 10% of the population in many PEAs, including PEAs relatively far down the population sorted list. *See* 2022 RKF Study. For example, RKF's methodology provides coverage to: 49% of New York, NY (PEA001); 50% of Los Angeles, CA (PEA002); 43% of San Francisco, CA (PEA004); 17% of Buffalo, NY (PEA054); and 28% of Laredo, TX (PEA221).

[30] *See* Starlink June 21, 2022 Submission at 5.

[31] The scaling used to determine 610,000 would be the total number of 5G macrocell base stations for nationwide coverage using the Las Vegas approach advanced by Starlink is shown in the following table:

Starlink 5G Base Station Assumptions Scaled Nationally	
2020 population of PEA026, Las Vegas	2,478,728
2020 population covered in PEA026 (70%)	1,735,110
Number of Base Stations assumed by Starlink	3,215
2020 covered POPs per Base Station	1,735,110 / 3,215 = 540
2020 CONUS population	329,260,619
Total Inferred Base Stations in CONUS	329,260,619/ 540 = **609,741**

Even if a 12 GHz licensee were to provide 5G wireless broadband service to "only" 70% of the country covered consistent with Starlink's minimum coverage assumption, Starlink's Las Vegas approach would

uses approximately 75,000 towers, or just 1/9th of the number implied by Starlink's claims, to support a fully nationwide mobile network across an entire portfolio of spectrum spanning from 700 MHz to 24 GHz.[32] Starlink envisioned an extremely dense 5G network buildout, which used 3,215 base stations to reach 70% of POPs in the Las Vegas PEA. This presumption compounded the effect of incorporating an unsustainable urban-suburban skew for NGSO terminals.

Fifth, Starlink's latest submission assumed 90% of Starlink subscribers would mount user terminals on their rooftops. In its 2021 coexistence study, RKF reasonably assumed 80% of Starlink terminals would be installed 1.5 meters above ground; however, Starlink claimed an unspecified "majority" of its end users would use a rooftop installation 4.5 meters above ground. RKF questioned Starlink's claim, but nonetheless re-ran the study in 2022 with an assumption that "55% of Starlink terminals"—a majority—"would be installed on rooftops with an HAGL [height above ground level] of 4.5m."[33] RKF's May 2022 Monte Carlo analysis, of course, found a negligible 0.15% risk of exceedance, even if a "majority"—*i.e.*, 55% of Starlink users—pursued rooftop self-installation of Starlink terminals at 4.5 meter elevations.

Starlink now asserts that fully *90%* of Starlink customers will self-install their terminals on rooftop locations 4.5 meters above ground. The Starlink submission simply cites "its own informal customer surveys" to support the new, 90% assumption.[34] Starlink offers no detail about these "informal surveys." There is no stated target population, sampling plan, data collection method, survey time, survey duration, sampling method, or error rate. The unsupported figure is also inconsistent with Starlink's advertising, market statements, business model, and consumer manuals.[35] *Starlink's only substantive defense of its 90% rooftop deployment assumption is to compare Starlink's model of self-installation to the professional-installation models of the nation's DBS providers, DISH Network and DirecTV*. Starlink's argument, at bottom, is that because the DBS providers install satellite antennas on customers' rooftops, Starlink will too. The argument lacks merit. DISH and DirecTV have hired, trained, insured, and supplied thousands of professionals to install DBS antennas on customers' rooftops. Starlink sells a kit and supplies a self-installation manual to those who purchase it. Starlink does not offer professional installation,

require 406,000 macrocells since 70% of the 2020 U.S. population is 230,482,433 and the same 540 POPs per base station figure would apply (230,482,433 / 540 = 426,819).

[32] *See* Mike Robuck, *AT&T Turns Up AI for Drones, Load Balancing, 5G Build Out*, Fierce Telecom (Sept. 26, 2019) https://www.fiercetelecom.com/telecom/at-t-turns-up-ai-for-drones-load-balancing-and-5g-build-out.

[33] *See* 2022 RKF Study.

[34] *See* Starlink June 21, 2022 Submission at 8.

[35] Starlink's public statements and advertising say that the Starlink kit "includes everything you need," and no mounting tools are required aside from a "base" that is specifically "designed for ground level installation." *See* Frequently Asked Questions, Starlink, https://support.starlink.com/ (last visited July 14, 2022) ("What comes in my Starter Kit? Your Kit includes everything you need to connect to the internet including your Starlink, WiFi router/power supply, cables, and base. The Starlink base is designed for ground level installation"); *see, e.g.*, Letter from David Marshack, Managing Director and Chief Operating Officer, RKF Engineering Solutions, LLC, to Marlene Dortch, Secretary, FCC, WT Docket No. 20-443 at 10 (Aug. 9, 2021) (raising this question); RS Access, May 7, 2021 Comments at 40 (explaining why RKF assumed 80% of terminals would be mounted on the ground).

and the notion that a majority of Starlink customers, much less 90% of them, will pursue a costly, complicated, and physically demanding rooftop installation strains credulity. Starlink's inflated claims about its customers' rate of rooftop installations exaggerate the likelihood that Starlink terminals will have line-of-sight exposure to a 5G base station.

Sixth, Starlink assumed a 5G base station EIRP of 75 dBm/100 MHz, a ten-fold increase in power over the 65 dBm/100 MHz value typical of 5G systems that RKF's most recent study reflected. By using 75 dBm/100 MHz in the May 2021 report, RKF was representing a worst case. The 75 dBm/100 MHz reflects the maximum power of the Part 30 EIRP level for millimeter wave bands. As reflected in RKF's May 2022 report, a reduction of base station transmit power to 65 dBm/100 MHz represents a more realistic average and is more reflective of common power amplifier capabilities and international standards.

Seventh, Starlink ignored the critical role of 5G advanced antenna technologies, such as horizon nulling, that reduce the likelihood of exceedance events. Contrary to Starlink's assertions, RKF's studies are designed to reflect the realities of current-generation 5G equipment, including 256-element antennas, and take care to explain how they promote coexistence. RKF's analysis and equipment assumptions rely on present-day technologies in-use and in the field today. For example, advances in antenna design and mobile network architecture that have made coexistence even more feasible, and enable 12 GHz mobile operators to deploy massive capacity at scale without interfering with service to NGSO and DBS users.[36] Reports from industry leaders like Qualcomm further indicate 256 element antennas are not only feasible, but also are considered the current standard for massive-MIMO technology.[37] Qualcomm indicates these 256 element antennas are used even at frequencies much lower than 12 GHz, where longer wavelengths require larger elements and spacing between elements.[38] Emerging technologies only promise greater economic and practical feasibility, suggesting even greater potential for wide-scale 5G deployment. The feasibility of phased-array antennas and their potential has been well known for decades, and advances in manufacturing technology have eroded any real barrier to deploying these higher-capacity antennas in wide-scale broadband deployments, especially in the 12 GHz range.

* * *

RKF stands by the accuracy of its technical studies, including its finding that 5G deployments would have no effect on at least 99.85% of NGSO operations in the 12 GHz band. The validity of any engineering observations depends on the capacity of that analysis to be reproduced. Reproducibility not only eliminates the potential for mere coincidence, but also allows for the testing of component assumptions that feed into the resulting technical conclusions. In 2021, RKF provided information detailed enough to allow third parties to reproduce its conclusions and contest the validity of its input assumptions. After the opponents of expanding terrestrial mobile

[36] *See, e.g.*, RS Access, May 7, 2021 Comments at ii-iii.

[37] *See Advanced Massive MIMO Technologies Usher in New Wide-Area 5G Capabilities*, RCR Wireless News (Mar. 8, 2022), https://rcrwireless.com/20220308/5g/advanced-mimo-technologies-usher-in-new-wide-area-5g-capabilities.

[38] *Id.*

access to the 12 GHz band challenged RKF's input assumptions, RKF re-ran its model with changed assumptions to demonstrate how even unrealistic input about elevation angles, antenna patterns, antenna height above ground, and other factors would still generate exceptionally low instances of exceedance into NGSO user terminals.

Starlink's belated submission in this proceeding, by comparison, was neither transparent, nor readily reproducible, and many of the assumptions that Starlink chose to disclose have proven to be deeply flawed. In its latest submission, Starlink claimed that NGSO terminals would experience a rate of exceedance more than 500 times the exceedance RKF had calculated would occur. RKF extracted the core assumptions embedded in Starlink's submission and has now successfully reconciled the vast majority of the Starlink claims with the results of RKF's 2022 study. RKF's reconciliation can account for 450 of the roughly 500-fold increase Starlink generated, or about 90% of the difference between Starlink's claims and RKF's study. In other words, only a 1.1x difference in results remains in the "Other" category. The technical showings, properly analyzed, therefore converge to the conclusion that the effect of 5G deployment on NGSO exceedance in the 12 GHz band is minimal.