December 20, 2019

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

Re: Written Ex Parte Presentation Regarding 1 dB Standard, **IB Docket Nos. 11-109 and 12-340; IBFS File Nos. SES-MOD20151231-00981; SAT-MOD-20151231-00090; SAT-MOD-20151231-00091; SAT-AMD-20180531-00044; SAT-AMD-20180531-00045; and SES-AMD20180531-00856**

Dear Ms. Dortch:

The GPS Innovation Alliance ("GPSIA") hereby responds to Ligado Networks, LLC's ("Ligado's") recently filed critiques of the Department of Defense's ("DoD's") position that the FCC should apply the "1 dB standard" to evaluate pending applications filed by Ligado.[1] Like many of Ligado's previous submissions in these dockets, its latest arguments demonstrate a lack of understanding of the engineering considerations that go into the design of navigation systems and devices. As discussed in detail below, the 1 dB standard is the only reliable mechanism to ensure adequate protection for the continued functioning of Global Positioning System ("GPS") and global navigation satellite system ("GNSS") receivers and the multitude of aviation, public-safety, and other uses that depend on a daily basis on the accuracy, continuity, integrity, and availability of these devices. The Commission must ignore Ligado's request that the Commission disregard the clear position, expressed by other parts of the U.S. government, that the 1 dB standard is appropriate for evaluating interference to GPS and GNSS devices.

1. Changes in C/N_0 Are a Direct Measure of Receiver Performance.

As noted extensively in the record, GNSS, as a radio navigation system, operates differently than radio communications systems. (GPS is the GNSS operated by the United States.) The primary measurement in GNSS is the timing of bit transitions in the navigation signal. Precise timing and positioning require sub-nanosecond measurement of bit edges. Accurate measurement of bit edges, in turn, requires wide receiver bandwidth; effective

[1] *See, e.g.*, Letter from Gerard J. Waldron, Counsel for Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (Nov. 25, 2019) ("Ligado Nov. 25, 2019 *Ex Parte* Filing"); Letter from Valerie Green, Ligado Networks, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (Nov. 21, 2019) ("Ligado Nov. 21, 2019 *Ex Parte* Filing").

multipath rejection also requires wideband signals. In addition, unlike communications systems, which operate above the noise floor – that is, the level of noise occurring naturally at a receiver before a new signal is introduced – spread spectrum GPS signals are below the thermal noise floor when they are received.[2] The cumulative effects of interference can easily increase the noise floor and degrade GPS performance. Even a small increase in the noise floor may affect a GPS signal's accuracy, integrity, continuity, or availability in unexpected or dramatic ways. Each of these parameters can be degraded by varying amounts by interference.[3]

Monitoring changes in a GNSS receiver's Carrier-to-Noise Power Density ratio ("C/N_0") provides a quantifiable and empirical measure of receiver performance that directly influences all four of these parameters. C/N_0 is directly related to signal to noise ratio ("SNR") and bit error rate ("BER") and is the actual measure of noise and stress in tracking loops. Its importance cannot be overstated. In fact, as experts note, "[a]n accurate measure of C/N_0 in each receiver tracking channel is probably the most important mode and quality control parameter in the receiver baseband area."[4] So like BER and SNR, C/N_0 is a direct measurement of receiver performance rather than a downstream measurement of use-case dependent parameters (such as

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[2] Phillip W. Ward, John W. Betz, and Christopher J. Hegarty, Interference, Multipath, and Scintillation, in UNDERSTANDING GPS PRINCIPLES AND PRACTICE, 247 (Elliot D. Kaplan and Christopher J. Hegarty eds. Artech House, 2d ed. 2006)("Kaplan & Hegarty").

[3] Accuracy is the difference between a GPS device's indicated position, velocity, and time ("PVT") and its actual PVT at any moment. Integrity is the ability of GNSS Systems to provide timely warning to users of problems in the system or equipment and to shut itself down when it is unable to meet necessary requirements. Continuity evidences GPS's ability to provide the required level of service without unscheduled interruption. Availability describes how often a GNSS system is available for use when it satisfies accuracy and integrity requirements. *See generally* Comments of Garmin International, Inc., IB Docket Nos. 12-340, *et al.*, at 9-12 (May 23, 2016).

"Non-interference with [radionavigation] RF spectrum is crucial. All domestic and international [radionavigation] services are dependent on the uninterrupted broadcast, reception and processing of radio frequencies in protected radio bands. Use of these frequency bands is restricted because stringent accuracy, availability, integrity, and continuity parameters must be maintained to meet service provider and end user performance requirements." *See* Depts. of Defense, Homeland Security, and Transportation, *2014 Federal Radionavigation Plan*, at 1-15 (2015, https://www.navcen.uscg.gov/pdf/FederalRadionavigationPlan2014.pdf(last visited Dec. 19, 2019).

[4] Phillip W. Ward, John W. Betz, and Christopher J. Hegarty, Satellite Signal Acquisition, Tracking and Data Demodulation, in Kaplan & Hegarty at 233.

position error); C/N_0 therefore, is the most appropriate measurement for consideration in any interference analysis.[5]

2. A 1 dB Degradation of C/N_0 Is a Direct and Early Indicator of Interference.

Not only does use of C/N_0 have great utility as an objective measure, but a particular metric – a 1 dB decrease in C/N_0 – has become a long-utilized and well-recognized interference indicator in the GNSS industry because of its reliability as a comprehensive metric. A decrease of 1 dB in C/N_0 has the effect of roughly a 25 percent increase in the noise floor due to interference.

Computed at the point where the GPS signal enters a receiver, signal degradation of 1 dB or more is sufficient to convert acceptable service to marginal service. Contrary to Ligado's assertions,[6] an observed decrease of 1 dB is, indeed, an accurate and reliable measure of interference, and adhering to it is essential for a number of safety-related reasons. For example, C/N_0 is a critical variable in the link budgets for certified aviation devices used in the Radio Frequency Interference analysis that underpins receiver performance standards considered by the Federal Aviation Administration ("FAA") and RTCA.[7] In the Wide Area Augmentation System ("WAAS"), there is less than 1 dB of margin available for additional interference beyond that which was envisioned in the existing standard.[8] With WAAS, "even small changes in the C/N_0

[5] C/N_0 is measured by receivers at frequent periodic intervals, such as 1 Hz, 5 Hz, or 10 Hz. Momentary fluctuations in C/N_0 yield insight into receiver function that otherwise may be masked by averaging. Use of C/N_0 as an interference metric allows system designers and spectrum regulators to carefully allocate interference to various sources as the net effect of interference is the sum of the individual sources, each of which has been expressed in dB. Use of C/N_0, in other words, permits both aggregation of interference and the apportionment of interference among multiple devices. Madhavendra Richharia and Leslie David Westbrook, SATELLITE SYSTEMS FOR PERSONAL APPLICATIONS: CONCEPTS AND TECHNOLOGY, Section 4.3 (John Wiley & Sons, Ltd. 2010).

[6] Roberson and Associates, LLC, *Implications of 1 dB C/N_0 for Spectrum Adjacent to GNSS*, at slide 3 (Nov. 25, 2019) ("Ligado Nov. 25 *Ex Parte* Appendix"), *attached to* Ligado Nov. 25, 2019 *Ex Parte* Filing.

[7] The link budget is a foundational equation amalgamating all system gains and losses (including known interference sources) from the GPS satellite to receiver. The link budget allows system designers to ensure sufficient link margin (and safety margin) exists to accommodate the known losses the system will encounter (*e.g.*, path loss, interference, etc.) when in use.

[8] WAAS is a regional space-based augmentation system operated by the FAA to provide essential and extremely accurate navigation information for civil aircraft operating throughout North

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link margin can have significant adverse consequences on receiver and ultimately navigation system performance."[9] As little as "a 0.4 to 0.6 dB difference in link margin, under certain scenarios, can change the WAAS word error rate by an order of magnitude."[10] WAAS represents a carefully engineered component of the GPS system in which the effects of many attenuation and interference sources have been taken into account to reach an operating point that meets strict aviation safety requirements. Reducing C/N_0 by 1 dB causes the system to no longer meet these requirements and can have serious aviation safety consequences.

A 1 dB reduction in C/N_0 will also cause a ten-fold decrease in the mean time between cycle slips in a GNSS receiver tracking loop. Most GNSS systems rely on continuous tracking of the signal carrier of each satellite being tracked to attain maximum accuracy. By continually tracking the carrier and measuring its phase at the time of measurement (the carrier phase), relative motion with respect to the satellites can be measured to sub-centimeter levels. A cycle slip interrupts this continuous carrier phase, forcing the tracking loop to reacquire the carriers and then re-initiate the carrier phase measurement. Lack of continuous carrier phase renders many high precision applications, such as earthquake monitoring, unavailable.

Equally important, degradation may occur before the point at which there has been a 1 dB reduction in C/N_0, or before the point at which the noise due to interference has increased by 25 percent.[11] This is particularly true in challenging use cases in which signal levels may be attenuated by foliage or structures (for example, suburban streets or "urban canyons," respectively) or in which signal reception is changing due to dynamic effects, such as large trucks passing on the highway or aircraft "pitch and roll" during normal maneuvering at takeoff, landing, or en route. It is critical that the margin established in the design of the GPS system for

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America. *See* FAA, Satellite Navigation – Wide Area Augmentation System (WAAS), https://www.faa.gov/about/office_org-/headquarters_offices/ato/service_units/techops/navservices/gnss/waas/howitworks/ (last visited Dec. 19, 2019); *see also* GPS, Augmentation Systems, Wide Area Augmentation System (WAAS), https://www.gps.gov/systems/augmentations (last visited Dec. 19, 2019). (Although WAAS is "designed primarily for aviation users, WAAS is widely available in receivers used by other positioning, navigation, and timing communities.").

[9] RTCA, Inc., *Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band*, RTCA/DO-235B, prepared by RTCA SC-159, at § 2.6.3, at 23 (Mar. 13, 2008).

[10] *Id.*

[11] Memorandum from National Space-Based PNT Executive Group, to Administrator, NTIA, Assessment of LightSquared Terrestrial Broadband System Effects on GPS Receivers and GPS-dependent Applications, at 4 (June 14, 2011), available at https://www.gps.gov/spectrum/lightsquared/docs/2011-06-NPEF-lightsquared-report.pdf (last visited Dec. 19, 2019).

effects such as these not be eroded by allowing persistent interference levels that may have less impact under ideal conditions.

Alternative metrics, such as key performance indicators ("KPIs"), that may indicate inaccuracy and other problems, only reveal these deficiencies at the time of operation, much farther downstream in the receiver, meaning that harmful interference may have already occurred, leaving the public safety or other user with mistaken and highly unreliable information in critical situations. For instance, safety-of-life aviation operations, such as the FAA's mandated ADS-B Out, precision approach and landing, and Terrain Awareness and Warning System all depend on the accuracy and integrity of the GPS signal; detecting signal interference, inaccuracies, or interruptions at the earliest possible point, before they may be detectable to operators, is essential. Similarly, on the ground, the increasing use of high-precision GNSS for autonomous vehicles – including driverless cars, automated construction equipment, and driverless agricultural machinery (for which integrity of the signal is critical for safety) – highlights the importance of detecting signal interference at the point when it first occurs and not farther downstream in the receiver.

Ligado's additional notion that data from a study conducted, at its request, by the National Advanced Spectrum and Communications Test Network ("NASCTN") show that there is no correlation between device function experienced by the user (such as position error) and a 1 dB reduction in C/N_0 is false.[12] In fact, as several submissions in the record demonstrate, the NASCTN test results, with respect to the insufficiently small sample of receivers that were tested, show a direct correlation between a 1 dB drop in C/N_0 and degradation of the particular KPIs analyzed; the NASTCN data, therefore, *support* use of the 1 dB standard to determine harmful interference.[13] Ligado's claims about the alleged unreliability of the 1 dB standard are belied by Ligado's own NASCTN data, which provide both direct and indirect support for the correlation between a 1 dB drop in C/N_0 and degradation of the KPIs that Ligado directed NASCTN to measure.[14]

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[12] Ligado Nov. 25 *Ex Parte* Appendix at slide 3.

[13] *See* Letter from F. Michael Swiek, GPS Innovation Alliance, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340, *et al*., July 13, 2017 at 3, 9-11 (July 13, 2017) ("GPSIA July 13, 2017 *Ex Parte* Filing").

[14] *See* Reply Comments of Garmin International, Inc., Docket Nos. 12-340, *et al*., at 3-4 (July 26, 2018); Letter from M. Anne Swanson, Counsel for Garmin International, Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, *et al.*, at 4-5 (May 16, 2018) ("Garmin May 16, 2018 *Ex Parte* Filing"). Also, it is well understood in the navigation industry that measuring changes in C/N_0 can be done both accurately and repeatedly. In addition to the consistency

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For instance, for high precision receivers, comparison of the C/N_0 plots from the NASCTN testing with the TTFF measurement for HPP and RTK receivers shows that TTFF performance degradation is concurrent with an interference-induced 1 dB drop in C/N_0.[15] The NASCTN test results also demonstrate a close correlation between degradation in C/N_0 and the position accuracy of the general location navigation receivers that NASCTN tested; in previous submissions, GPSIA provided many specific examples from the NASCTN report, showing a direct correlation between a 1 dB drop in C/N_0 and degradation of device performance, substantiating the appropriateness of using a 1 dB metric.[16]

Ligado's mono-focus on KPIs, and position error in particular, also ignores that position measurement is only one aspect of GPS receiver operations. In some applications, the primary receiver output may not even be position, but rather time, velocity, acceleration, or some other characteristic. This is particularly true in the banking industry for which GNSS serves as a key source of timing information, allowing the industry to keep track of electronic payments, withdrawals, and transfers. Throughout the Ligado submissions, the effect of potential interference on these other uses of GNSS receiver outputs has been essentially ignored. Utilization of a 1 dB C/N_0 metric provides a standard measure and removes the need to add these characteristics to the administratively unwieldy list of items that Ligado's user- or performance-

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disclosed in the U.S. Dept. of Transportation Adjacent Band Capability Study ("DOT/ABC Study") results, DOT included linearity testing, which varies the GPS signal level in 1 dB steps and confirms that the reported C/N_0 also changes by 1 dB. U.S. Department of Transportation, *Global Positioning System (GPS) Adjacent Band Capability Assessment*, Final Report, at 41 (Apr. 2018) ("DOT/ABC Final Report"); *see also* Hadi Wassaf, *et al.*, *GPS-ABC Radiated Chamber Testing Overview and Results, GPS-ABC Workshop VI* , at 2 and 22, U.S. Dept. of Transportation (Mar. 30, 2017), https://rosap.ntl.bts.gov/view/dot/31391.

[15] *See* GPSIA July 13, 2017 *Ex Parte* Filing at 9 (discussing William F. Young, *et al.*, LTE IMPACTS ON GPS (2017)). *See also* GPSIA July 13, 2017 *Ex Parte* Filing at 9-10 and Appendix, Table 1 of the *Ex Parte* Filing. The NASCTN testing evaluated the operation of high-performance positioning ("HPP") and real-time kinematic ("RTK") receivers with respect to both C/N_0 degradation and time to first fix ("TTFF") performance in the presence of interference. TTFF affects the *availability* of the high precision position information. Similarly, the need for increased time to re-acquire satellites and to fix cycle ambiguities in a high precision receiver can significantly degrade performance for the end-user. Many high-precision applications (*e.g.*, on heavy machinery) require *availability* near 100% for users to gain full utility and productivity from their equipment.

[16] Garmin May 16, 2018 *Ex Parte* Filing at 5-6 and n.15; GPSIA July 13, 2017 *Ex Parte* Filing at 10.

centric approach would require to be tested. The 1 dB standard addresses performance across all device types and users.

In addition to the NASCTN data, the results of the Department of Transportation Adjacent Band Compatibility Study ("DOT/ABC Study") also demonstrate that a 1 dB degradation in C/N_0 detracts noticeably from receiver performance. As the DOT/ABC Study noted, "[t]he results of these tests indicate that the 1 dB [C/N_0] degradation level is a good indicator of the region where acquisition starts to be impacted for some receivers." [17] This is especially noticeable for the GNSS signals from low elevation satellites or GNSS signals attenuated due to foliage or other environmental factors. In some instances, receivers under test failed to acquire low elevation satellites at the 1 dB interference level. At the point of 1 dB degradation, experts acknowledge that devices experience loss-of-lock for one or more satellites.[18]

3. Short-Term Variations in GPS Signals Do Not Impact the Use of the 1 dB Standard To Identify Interference.

Short-term variations in C/N_0 occur naturally and are a fact of life; they provide no basis for challenging use of a 1 dB degradation in C/N_0 as an interference protection criterion for GNSS. C/N_0 can experience temporal fluctuations as a receiver undergoes the dynamics of normal use. These variations do not negate the efficacy of C/N_0 as the appropriate tool for assessing interference to GPS receivers.

C/N_0 is incredibly stable in laboratory environments when interference is being assessed. A 1 dB change – with or without interference – is a very repeatable measurement. By averaging the reported C/N_0 measurements over a period of one minute, the fluctuations can be reduced to well under 1 dB. The results of the DOT/ABC Final Report validate the repeatability of 1 dB measurements. On multiple days, the DOT team conducted the same test and then compared the

[17] DOT/ABC Final Report at 156; *see id.*at 65-67.

[18] Christopher Hegarty, *et al.*, Loss of Lock Analysis, *GPS-ABC Workshop VI*, at 6 U.S. Dept. of Transportation (Mar. 30, 2017), *available at* https://rosap.ntl.bts.gov/view/-dot/32102 (last visited Dec. 19, 2019); U.S. Dept. of Transportation, *GPS Adjacent Band Compatibility Assessment*, Space-Based PNT Advisory Board, at slide 16 (Dec. 7, 2016), *available at* https://www.gps.gov/governance/advisory/meetings/2016-12/vandyke.pdf (last visited Dec. 19, 2019).

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results, finding the "[r]esults showed good consistency between [repeated] tests."[19] Comparison of radiated and wired tests also demonstrated this consistency, revealing loss in performance at 1 dB degradation.[20]

Ligado's latest attack on the 1 dB standard as not qualifying as a standard and as being "measured and reported inconsistently and mostly incorrectly" [21] ignores that this metric is not a measure of interference *per se*, but rather a tool to measure when interference occurs in a GNSS receiver. Ligado's further criticism that "a GPS receiver's C/N_0 varies by more than 1 dB in good signal conditions [and] [d]evice reported C/N_0 for the same interference level *varies from device to device*" completely overlooks several important factors.[22] GNSS receiver manufacturers must necessarily plan for system margin to account for variations in the real-world environment such as atmospheric changes, multipath, and other obstructions. Such margins must not be allowed to be eroded by persistent, wide-spread interference never envisioned when the margins were established. Further, the variations in measurement to which Ligado now alludes are short-term, relatively instantaneous fluctuations that occur when measuring any physical phenomenon – fluctuations that scientists and engineers routinely deal with and successfully measure. By contrast, the effect of interference on GPS signals represents a persistent degradation bias – a phenomenon easily observed and measured, as multiple tests have shown.[23] Like many of its other assertions, Ligado's measurement variation arguments demonstrate a lack of understanding of the distinctive engineering considerations that go into the design of radio navigation systems.

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[19] Stephen Mackey and Hadi Wassaf, *GPS-ABC Radiated Chamber Testing Overview and Results*, *GPS-ABC Workshop V*, at 20, U.S. Dept. of Transportation (Oct. 14, 2016) at 20, https://rosap.ntl.bts.gov/view/dot/31391.

[20] Karl Shallberg, *GPS-ABC Workshop Wired (Conducted) Test Results*, *GPS-ABC Workshop V* at 17, U.S. Dept. of Transportation (Oct. 14, 2016), https://rosap.ntl.-bts.gov/view/dot/31375.

[21] Ligado Nov. 21, 2019 *Ex Parte* Filing at 9.

[22] Ligado Nov. 25 *Ex Parte* attachment at 3.

[23] Various tests have been conducted using the 1 dB standard, including the initial TWG testing in which Ligado participated. *See*, for example, LightSquared Subsidiary LLC and the United States Global Positioning System Industry Council (the technical working group ("TWG")), Final Report, IB Docket No. 11-190, at 24 (June 30, 2011), http://licensing.fcc.gov/myibfs/download.do?attachment_key-=900848 (last visited Dec. 19, 2019). The TWG test conclusions for Space-based Receivers are contingent on a measured 1 dB drop in C/N_0, a fact that Ligado never contested at the time.

4. Ligado's Claim That Use of the 1 dB Standard Lacks Domestic or International Precedent Is Wrong and Seems To Be Based on an Incorrect Understanding of the Relationship Between C/N_0 and the GPS Noise Floor.

Understood as a protection against increases in the noise floor, the 1 dB standard has been used domestically and internationally for years in various contexts. As a review of regulatory history by the U.S. Air Force recounted, a 1 dB decrease in C/N_0 was employed as the interference protection criterion for GPS receivers in the FCC's rulemaking on Ultra-Wide Band ("UWB").[24] In that proceeding, the FCC interference criterion used to develop emission limits for UWB systems was based on a total rise in the noise floor of GPS receivers of 1 dB, which has the same effect as decreasing C/N_0 by 1 dB.[25] Shortly thereafter, the FCC again used the same criterion of a 1 dB rise in the noise floor in devising rules for limiting emissions of Low-Power Television ("LPTV") stations into the GPS band.[26]

Internationally, the ITU Table of Frequency Allocations of the international Radio Regulations allocates the bands where GPS/GNSS operate to the Radionavigation Satellite Service (RNSS). Accordingly, the ITU provides characteristics and protection criteria for receiving earth stations operating in the 1 559-1 610 MHz band.[27] As multiple commenting parties have shown, a 1 dB increase in the noise floor is also represented as an interference to noise ("I/N") ratio of -6 dB. In this form, the metric has been used in numerous ITU proceedings.[28] Indeed, as technologies have proliferated, experts and regulatory bodies have applied the 1 dB standard to govern both out-of-band emissions ("OOBE") and overload

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[24] U.S. Air Force, SMC/GP (GPS Directorate), *Background Paper on Use of 1-dB Decrease in C/N_0 as GPS Interference Protection Criterion*, at 3 (June 2017) ("USAF Paper"), www.gps.gov/spectrum/ABC/1dB-background-paper.pdf (citing *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, Memorandum Opinion and Order and Further Notice of Proposed Rule Making, 18 FCC Rcd 3857 (2003)).

[25] USAF Paper at 3.

[26] *Id.* at 3 (citing Letter from Fredrick R. Wentland, Office of Spectrum Management, NTIA, to Edmond J. Thomas, Chief, Office of Engineering and Technology, FCC, MB Docket No. 03-185 (Aug. 27, 2004)).

[27] *See* ITU-R, Recommendation ITU-R M.1903.1, at 3 (Sept. 2019) (specifically recommends "that the characteristics and protection criteria of receiving earth stations given in [the annex for all receiver types] should be used in performing analyses of the interference impact on RNSS (space-to-Earth) and certain ARNS receivers . . . operating in the band 1 559-1 610 MHz from radio sources other than in the RNSS").

[28] USAF Paper at 3-4; Garmin May 16, 2018 *Ex Parte* Filing at 2-4.

interference from services into adjacent bands, including the RNSS band.[29] In such instances, it is essential to determine the aggregate effect of the distinct types of interference originating from a common source; the 1 dB standard is the appropriate standard for evaluating harmful interference from adjacent band services because it successfully and holistically aggregates increases in the noise floor from OOBE alongside degradation from overload interference.

5. DOT Conclusions Based on GPS L1 Signals Cannot Not Be Extrapolated to Other Bands.

The test data and analysis in the DOT/ABC Study were limited to the frequencies adjacent to GPS L1, ranging from 1475 to 1675 MHz. No other frequencies, bands, or services were addressed. The DOT/ABC Study evaluated different categories of receivers operating in the L1 band because, just as the GPS in a smart-phone is different than the GPS in an airplane, different categories of receivers are unique and designed for specific purposes.[30] The various categories of receivers in the study required different interference tolerance masks, and those masks were asymmetrical. The interference tolerance levels above the GPS L1 band were different than those below the GPS L1 band. In other words, the results were frequency-dependent – the interference level at one frequency cannot be arbitrarily applied to another frequency.[31] The 1 dB standard was the measure by which all of those tests were conducted.[32]

In its November 25, 2019 filing, Ligado engages in unfounded extrapolation from the DOT data and conclusions, absent any technical analysis of its own, contending that use of the 1 dB standard would impose severe technical limitations on communications services operating near the GPS L2 and L5 bands, far away from the L1 band that DOT studied. L1 operates at 1575.42 MHz; L2 operates at 1227.6 MHz; and L5 operates at 1176.45 MHz. The modulation scheme, transmit power, and bandwidth all vary between the L1, L2, and L5 bands. The spectrum environment around each of these bands is likewise unique, with the service types, transmitter characteristics, deployment scenarios, and antenna parameters all varying

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[29] *See* ITU-R, Recommendation ITU-R M.1461-2 at Annex 1, Section 3 (Jan. 2018); ITU-R, Recommendation ITU-R M.2059-0 at Annex 3, Section 2 (Feb. 2014) (*generally*, and *specifically* Sections 2.1, 2.2); USAF Paper at 3 and n.4 (discussing use of 1 dB standard for developing emission limits for LPTV stations into GPS band). *See generally* USAF Paper at 2-4, 6-9.

[30] *See* DOT/ABC Final Report at 22-25.

[31] As the interference tolerance masks that were developed by DOT for the L1 band show, a given receiver category's ability to tolerate interference is highly frequency dependent. *See id.* at 45. *See* further the ITM's graphed in Appendix B to the DOT/ABC Final Report and not the frequency asymmetries (*e.g.*, Figure B-7).

[32] *See* DOT/ABC Final Report at 44-45.

significantly. These factors together directly affect the ability of GNSS receivers to coexist with nearby services.

By contrast, Ligado's November 25, 2019 filing appears to suggest that the interference tolerance levels at a particular frequency offset from L1 can be applied directly to other bands that were not studied by DOT. The spectrum environments around the GPS bands that Ligado mischaracterizes are completely different, and its arguments are based on misappropriation of the DOT test results. The only concrete and verifiable information in this proceeding relates to the GPS L1 band. In contrast, Ligado has manufactured wholly hypothetical obstacles to make unsupported statements about regulation of spectrum many megahertz away from GPS L1.

6. The Commission Must Consider DoD Concerns.

Ligado also suggests that the Commission can ignore or discount DoD's position on the use of the 1 dB standard. Ligado asserts that, while DoD has statutory authority to sustain and operate GPS, the Commission has "the *exclusive* authority to determine how spectrum should be allocated and used" and thus should approve its pending modification applications notwithstanding DoD's concerns.[33]

The FCC clearly has jurisdiction over non-federal use of spectrum, and it is responsible for determining how that spectrum should be allocated and used.[34] But, that does not mean that the Commission is free to ignore critical input from DoD when making those decisions. As Ligado correctly observes, the Commission is required to make spectrum decisions based on facts and analyses in the record.[35] Indeed, the Administrative Procedure Act ("APA") requires agencies to consider the "relevant matter presented" while engaging in the rulemaking process.[36]

In this case the Commission should not merely *consider* DoD input on the 1 dB standard in satisfying its APA requirements. Instead, to the extent federal entities are impacted by the Commission's decisions, the Commission should give *greater consideration* to concerns that DoD raises. *First*, the Commission and NTIA – the agency that is responsible for managing the use of spectrum by federal entities and that has conveyed letters supporting the 1 dB Standard to the FCC[37] – are required by statute to work together to ensure that spectrum policy decisions

[33] Ligado Nov. 21 *Ex Parte* Filing at 3.

[34] *See* 47 U.S.C. § 151 *et seq.*

[35] *See* Ligado Nov. 21 *Ex Parte* Filing at 3; *see also* 5 U.S.C. § 500 *et seq*.

[36] 5 U.S.C. § 553(b).

[37] Letter from Douglas W. Kinkoph, Deputy Asst. Secretary for Communication and Information (Acting), to The Honorable Ajit Pai, Chairman, FCC, IB Docket No. 11-109 (filed Dec. 6, 2019),

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promote the efficient use of spectrum consistent with both the economic interests and national security of the Nation.[38] To implement that requirement, the two agencies have entered into a Memorandum of Understanding under which each agency is required to give the other notice of, and the opportunity to comment on, all proposed actions that could potentially interfere with the other's spectrum management decisions.[39] It would be illogical for the Commission to simply disregard or discount what DoD and NTIA have provided. As the *FCC-NTIA MOU* directs, the agencies should endeavor to resolve technical, procedural, and policy differences by consensus whenever possible.[40]

Second, the Commission has incorporated feedback from NTIA and federal agencies throughout this proceeding,[41] and there is no reason for it to stop now. In fact, in its 2011 *Conditional Waiver Order*, the Commission specifically required that Ligado, as a condition of commencing its previously proposed operations, complete an "Interference Resolution Process," which the Commission defined as the point at which "the Commission, *after consultation with NTIA*, concludes that the harmful interference concerns have been resolved and sends a letter to [Ligado] stating that the process is complete."[42] It was because NTIA expressed its continued

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transmitting recommendations, as Ligado observes, from other agencies that focused on the 1 dB standard. *See* Letter from Gerard J. Waldron, Counsel to Ligado Networks, LLC to the Honorable Ajit Pai, IB Docket No. 11-109 (Dec. 8, 2019) at 2.

[38] *See* 47 U.S.C. §§ 922 (directing NTIA and the FCC to meet, at least biannually, to conduct joint spectrum planning with respect to certain issues, including "to promote the efficient use of the spectrum, including spectrum management techniques to promote increased shared use of the spectrum that does not cause harmful interference as a means of increasing commercial access"); 902(b)(2)(L)(i) (requiring NTIA to develop, in cooperation with the FCC, a comprehensive long-range plan regarding spectrum management).

[39] *See* Memorandum of Understanding between the Federal Communications Commission and the National Telecommunications and Information Administration (Jan. 31, 2003) ("*FCC-NTIA MOU*"), https://docs.fcc.gov/public/attachments/DOC-230835A2.pdf.

[40] *See FCC-NTIA MOU* at 3.

[41] *See, e.g.*, *International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver*, Public Notice, 27 FCC Rcd 1596, 1597 (2012) ("*Conditional Waiver Public Notice*") ("The Commission received and incorporated into each of those rules extensive input from the public and federal agencies.").

[42] *LightSquared Subsidiary LLC; Request for Modification of its Authority for an Ancillary Terrestrial Component*, Order and Authorization, 26 FCC Rcd 566, ¶ 43 (2011) (*emphasis added*); *see also Conditional Waiver Public Notice*, 27 FCC Rcd at 1598.

concern about the potential interference to GPS operations from Ligado's network that the Commission determined that the Interference Resolution Process had not been successfully completed and requested comment on whether Ligado's terrestrial authorizations should be suspended indefinitely.[43] The Commission must take the same approach here with respect to other departments' and agencies' positions.

Finally, the Commission routinely gives deference to agencies and their technical positions, such as the 1 dB standard, in other contexts, particularly when they are the expert agency on an issue. For example, the Commission declined to approve the Sprint/T-Mobile merger until several months after the Department of Justice – the agency responsible for reviewing the antitrust effects of telecommunications merger – reached a satisfactory settlement.[44] In addition, the FCC often defers to the Federal Trade Commission on matters related to consumer privacy.[45] Earlier this month, in its radiofrequency exposure proceeding, the Commission deferred to the findings of the Food and Drug Administration ("FDA") that cell phones do not cause health problems, noting that the FDA is the "expert agency regarding the health impacts of consumer products."[46] Because NTIA and DoD are the expert agencies on federal spectrum use and sustaining GPS operations, as Ligado itself concedes, the Commission should heed – not reject – the material both have provided regarding the 1 dB standard when considering Ligado's modification applications.

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[43] *See Conditional Waiver Public Notice*, 27 FCC Rcd at 1598; *see also Comment Sought on Ligado's Modification Applications*, Public Notice, 31 FCC Rcd 3802, 3804 (2016) ("Noting that the process had not been successfully completed and that potential interference concerns had not been resolved, the Bureau sought comment on whether LightSquared's ATC authorizations should be suspended indefinitely.").

[44] *See, e.g., Applications of T-Mobile US, Inc., and Sprint Corporation*, Memorandum Opinion and Order, Declaratory Ruling, and Order of Proposed Modification, WT Docket No. 18-197, *et al.*, FCC 19-103, ¶¶ 33-36 (rel. Nov. 5, 2019).

[45] *See, e.g.*, Restoring Internet Freedom FCC-FTC Memorandum of Understanding (Dec. 14, 2017) https://www.ftc.gov/system/files/documents/cooperation_agreements/fcc_fcc_mou_internet_freedom_order_1214_final_0.pdf; Comment of the Staff of the Bureau of Consumer Protection of the Federal Trade Commission, WC Docket No. 16-106 (filed May 27, 2016).

[46] *Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields*, Resolution of Notice of Inquiry, Second Report and Order, Notice of Proposed Rulemaking, and Memorandum Opinion and Order, ET Docket No. 19-226, FCC 19-128, ¶ 2 (rel. Dec. 4, 2019).

7. Conclusion.

For the reception of low power, spread-spectrum signals such as GPS, the management of the noise floor and spectrum neighborhood is the only practical means of ensuring the RF environment is sustained and that GPS devices and systems used in aviation, public safety, and other sectors continue to function. Use of the 1 dB standard not only avoids harmful interference to GPS receivers, but, consistent with U.S. National Space Policy, it also sustains the overall radio frequency environment in which critical U.S. space systems, like GPS, operate. Given the unique concerns raised by maintaining this environment, it is not at all arbitrary or capricious to utilize the 1 dB standard in evaluating Ligado's pending applications that propose terrestrial uses in close spectral proximity to space-based operations.

Sincerely,

David Grossman

J. David Grossman
Executive Director
GPS Innovation Alliance

cc by email:
The Honorable Ajit Pai
The Honorable Michael O'Rielly
The Honorable Brendan Carr
The Honorable Jessica Rosenworcel
The Honorable Geoffrey Starks