Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the Matter of	)	
	)	
LightSquared Technical Working Group Report	)	IB Docket No. 11-109
	)	
	)	
LightSquared License Modification Application, IBFS Files Nos. SAT-MOD-20120928-00160, -00161, SES-MOD-20121001-00872	)	IB Docket No. 12-340
	)	
	)	
New LightSquared License Modification Applications IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091	)	IB Docket No. 11-109; IB Docket No. 12-340
	)	
	)	
Ligado Amendment to License Modification Applications IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091	)	IB Docket No. 11-109
	)	
	)	

OPPOSITION TO PETITIONS FOR RECONSIDERATION OR CLARIFICATION

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EXECUTIVE SUMMARY

Several entities have petitioned the Federal Communications Commission to reconsider its Order and Authorization allowing Ligado to deploy a terrestrial 5G network in its licensed L-band spectrum. An analysis of the petitioners' major reasons supporting reconsideration was conducted and compared to the evidence and discussion in the Order itself. The analysis reveals that the Order has considered and addressed the petitioners' concerns--and importantly, no new evidence has been brought to light that would justify reconsideration. For this reason, the Petitions for Reconsideration should be denied.

Petitioners allege the following as evidence supporting reconsideration: the spectrum will not provide value for 5G services; the GPS compatibility tests do not support the ability of GPS devices to operate without harm in the presence of Ligado's terrestrial service; a "1 dB C/N_0" degradation estimated by any GPS receiver is the appropriate metric for assessing GPS compatibility; the Ligado commitment to mitigate any harm to GPS devices is impractical and inadequate; the Order relies on an improper analysis of interference with Iridium; and the agreements between Ligado and GPS device manufacturers regarding Ligado operating parameters cannot be relied on in the Order. Analysis of each of these items, however, reveals that they lack factual basis and are contrary to the record and evidence presented in the Order.

Regarding the value of the Ligado spectrum for 5G services, petitioners allege that the amount of spectrum authorized for terrestrial service is insufficient to support 5G services and therefore does not provide societal value. The Order,

however, directly addresses and confirms the value of the spectrum especially for 5G Internet of Things (IoT) uses, one of cornerstones of 5G capabilities, and Ligado's stated target commercial application.

Regarding the three GPS compatibility tests conducted, evaluated, and discussed in the Order, petitioners allege that the Commission did not properly evaluate the test results, and that those results show that Ligado's terrestrial operations will harm GPS receivers. Contrary to this assertion, however, as indicated in the NTIA Petition itself, the FCC Office of Engineering and Technology participated in a Technology Focus Group (TFG) with all government stakeholders, reviewed all the test data and results, and formed its opinion based on two of the tests (NASCTN and Roberson and Associates) that measured the impact of Ligado's terrestrial service on GPS device functionality, which is the long established and accepted criteria for assessing harm due to interference.

Regarding the petitioners' assertion that the Order fails to recognize that a "1 dB C/N_0" degradation is the established metric for assessing GPS adjacent band compatibility, the Order clearly and correctly states that harm to the *functionality* of a GPS device (primarily positioning or timing) is the firmly established criteria for assessing the impact of interference, and that there is no precedent in any standard or international forum for using a degradation in C/N_0 as a criteria for measuring compatibility between a service in a separate second band some distance away from a desired band. In addition, the Order noted[1] that the compatibility testing showed that a 1 dB C/N_0 degradation did not reliably correlate with the impairment of the

[1] Paragraph 100 from FCC-20-48A1

functionality of GPS devices, whether those devices were used for positioning, timing, or other functions.

Petitioners assert that Ligado's commitment to remedy any harm to any GPS device is impractical, and an admission that harm will occur. Specifically, petitioners allege that replacing GPS antennas on High Precision receivers, for the few devices in the sole category of receivers that exhibited impairment in the Roberson and NASCTN coexistence tests, is impractical. The Order clearly discusses the Ligado requirement to provide this remedy in the highly unlikely event that a device would experience actual impairment.

The Iridium Petition for Reconsideration asserts that the Order did not adequately address the issue of Ligado OOBE limits and was dismissive of Iridium's three technical concerns. Scrutiny of the Order, however, reveals that the Order addresses each of these issues in detail and describes the reasons why the Iridium concerns are resolved. Iridium's petition raises no new issues and the proceeding shows their participation, so their assertions are clearly without merit.

Finally, petitioners assert that the agreements between Ligado and various GPS device manufacturers regarding Ligado terrestrial parameters cannot be relied on in the Order to establish regulatory requirements for coexistence with Ligado operations. The Order rightly and in considerable detail describes the technical elements of the agreements that were struck with Garmin, Deere, and Trimble. The description of the technical aspects of the agreements was supplemented in the Order by relevant elaboration by individuals and groups with expertise in the area.

Whether the agreements are called “coexistence agreements” or “settlement agreements” as some of the petitioners would prefer is irrelevant to the fact that they establish operating parameters for Ligado that the Commission was reasonable to assume meet the needs of GPS device manufacturers.

For the above reasons amplified in the remainder of the filing, the petitioner’s arguments present no new information and therefore fail to form an acceptable basis for the FCC’s reconsideration of the Order.

1 INTRODUCTION

Petitioners raise a variety of issues that they claim merit reconsideration of the Commission's approval of the Ligado Order, including issues related to the value of Ligado's spectrum for 5G, the appropriateness of the compatibility tests, the 1 dB metric, concerns related to co-existence with Iridium, and the agreements reached with GPS manufacturers. However, an examination of the Commission's order on Ligado's applications demonstrates that none of these issues provide the basis for reconsideration.

2 VALUE OF LIGADO SPECTRUM FOR 5G

Concerns were raised that the Ligado spectrum would not support the deployment of 5G.[2,3,4] The Order correctly discusses that Ligado's network is envisioned to support elements of two of the three "cornerstones" of 5G - massive machine type communication and ultra-reliable and low latency communications."[5] Ligado spectrum is very suitable for "network control and customization, and highly reliable performance 5G private networks seek to provide to industrial facilities."[6]

The Order will enable Ligado to "deliver focused, highly secure and ultra-reliable communications over custom private networks to specific geographic

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[2] "Moreover, Ligado will not even offer full 5G services; it will merely provide limited IoT services for select sectors." Page 8 of AEM Petition for Reconsideration

[3] "Ligado's proposed IIOT service does not meet any definitions of 5G." page 21 of Lockheed Martin Ligado PFR (5.22.2020)

[4] "The Order barely addresses the alleged public interest benefits of Ligado's offering. …– including its incorrect contention that its service will promote 5G" page 4 of PUBLIC REDACTED Iridium et al PFR-c3

[5] Paragraph 23 from FCC-20-48A1

[6] Paragraph 22 from FCC-20-48A1

locations" that serve the IIoT (Industrial IoT) market for railroads, trucking, utilities, public safety, oil and gas, aviation, autonomous vehicles, and other critical infrastructure industries."[7]

Ligado's use of the spectrum enabled by the Order will provide meaningful deployment of 5G needed by the United States and this contention is supported by traditional infrastructure providers for the U.S., Nokia and Ericsson.[8]

3 APPROPRIATENESS OF THE COMPATIBILITY TESTS

In reaching the FCC 5-0 decision to adopt the Order adopting the Ligado license modification, valuable spectrum desperately needed for the U.S. push into 5G is made available. To reach this decision, the FCC considered an extensive body of GPS device performance measurement data and comments from the large number of interested parties. Petitioners suggest that the GPS performance measurements taken on a variety of GPS devices by three different organizations were inappropriately considered and the decisions drawn from the tests were therefore flawed.

The Order's analysis of the record from all three testing efforts is both thorough, and it clearly shows that the proposed Ligado deployment will not affect the performance of the preponderance of GPS devices.

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[7] Paragraph 21 from FCC-20-48A1

[8] "Ligado is also working with 5G vendors Nokia and Ericsson to explore ways to support 5G services with features that could improve coverage, capacity, inter-network operability, and lower latency.79 Nokia and Ericsson have conducted studies to formulate specific inputs for Ligado's 3GPP plan to standardize and commercialize the Ligado spectrum band", Paragraph 23 from FCC-20-48A1

Roberson and Associates (RAA), a Technology Consultancy whose personnel have many decades of experience designing, building, and shipping billions of wireless devices, including GPS devices, performed the first set of tests.[9] The testing was directly funded by Ligado Networks to determine the presence or absence of harmful interference to GPS receivers based on the terrestrial deployment of Ligado spectrum. The proposed testing plans were based on the power and emission parameters in the December 2015 applications and were published, submitted to the record, widely distributed and all outside inputs, especially those from the GPS manufacturers, were carefully reviewed and incorporated into the test plans.[10] These inputs led to a requirement to measure devices under conditions of motion as was strongly suggested by Garmin and other GPS manufacturers. In the end, the this was the only test that performed this challenging form of measurement and was offered before the FCC for consideration.[11]

The RAA testing was performed at a commercial test house using certified equipment. 27 devices were tested covering four of the traditional categories of GPS devices – General Location, High Precision, Cellular and Non-Certified Aviation.[12] In the test results the manufacturer and model number are identified for each device.

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[9] "The RAA testing (discussed in its May and June 2016 reports) examined key performance indicators (KPIs), a form of performance-based metrics, to test how GPS devices perform with respect to accurately providing position measurements. RAA tested 27 GPS devices in early 2016—including cellular (using industry-standard metrics developed by 3GPP), general location/navigation (examining two-dimensional (2D) position error), non-certified aviation (same), and high-precision receivers (examining three-dimensional (3D) position error)." Paragraph 37 from FCC-20-48A1

[10] RAA test plan can be obtained here https://www.fcc.gov/ecfs/filing/60001098583

[11] Page 17 of Trimble – Petition for Reconsideration of Ligado Order

[12] Paragraph 37 from FCC-20-48A1

This was the only study where this data was made publicly available in the record. The test plans were also described in fine detail so the test was repeatable, verifiable, and able to be proven true or false, thus presenting a test system that could easily be repeated by another testing organization. Collecting the test data required 3941 hours of in chamber test time and the results, including raw data, were published and filed with the FCC and also shared with the NTIA.[13]

The primary criteria for the test was consistent with the FCC definition of harmful interference, i.e. during the varying test conditions, do the devices continue to work and perform as expected by the user.[14] These parameters were identified as key performance indicators (KPIs) with a particular focus on the two-dimensional and three-dimensional position error. The test also captured the Carrier Power divided by the Noise power density (C/N_0) for those devices that reported this information. The testing showed that most of the devices were compatible with the 2016 proposed Ligado deployment, which at the time had a transmit power level of 32 dBW or 1585 Watts for the so-called Lower Downlink at 1526 - 1536 MHz. This power level was further reduced to 9.8 dBW in Ligado's May 2018 Amendment.[15]

The only area of observed concern at this power level for 1526 - 1536 MHz was that several High Precision GPS devices experienced interference. Some of these were resolved by replacing the factory antenna with a filtered antenna (which

[13] Roberson and Associates, Final Report: GPS and Adjacent Band Co-Existence Study (June 10, 2016)

[14] "We then conclude, … that a performance-based metric approach—which more closely aligns with the Commission's "harmful interference" definition—is more reliable and should be used when evaluating the harmful interference concerns pertaining to GPS receivers." Paragraph 37 of FCC-20-48A1. [May want to add the Harmful Interference definition itself here.]

[15] Paragraph 15 of FCC-20-48A1

Ligado is committed to supply if needed).[16] As Ed Drocella points out "a 1 dB C/N_0 degradation is more likely to occur when the filtered GPS receiver bandwidth extends outside of the RNSS allocation."[17] Reducing the power level to 9.8 dBW means "that some of the high-precision GPS receivers that had been affected at 32 dBW levels would no longer be affected."[18]

A full report on the testing process and the test results was presented to representatives from the FCC, NTIA, and the Air Force GPS organization, at the Northern Virginia Test Facilities where the tests were performed to enable those in attendance to not only receive the report, but to also see the facilities used to perform the test as well as the actual devices that were tested.

The second set of tests was performed by **NASCTN (National Advanced Spectrum and Communications Test Network),** which is a multi-agency partnership sponsored and funded by the Department of Defense and the Department of Commerce.[19] The organization is associated with NIST (National Institute of Standards and Technology), the organization that provides the time and measurement standards for the United States. This organization and associated facility were explicitly created for the purpose of definitively resolving interference

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[16] Paragraph 80 of FCC-20-48A1

[17] Page 3 of Ed Drocella Declaration attached to the NTIA Petition for Reconsideration in Ligado Proceedings

[18] Paragraph 82 of FCC-20-48A1

[19] "The National Advanced Spectrum and Communications Test Network (NASCTN) is a multi-agency, chartered partnership that seeks to provide a "neutral forum" for testing, modeling and analysis necessary to inform future spectrum policy and regulations. In 2017, NASCTN issued its report, which Ligado had earlier commissioned. In this project, NASCTN developed a test method to investigate the impact of adjacent band LTE transmissions on GPS receivers in tracking and reacquisition modes." From paragraph 38 of FCC-20-48A1

testing issues like the one in question with Ligado and GPS. In fact, the impetus for creating the facility and organization was the 2011 LightSquared – GPS issue.

The testing was performed at the request and direction of senior DoD personnel in the Defense Information Systems Agency (DISA, the Information Technology organization of the DoD), and had DoD personnel involvement in all aspects of the test from beginning to end. A senior member of the DISA organization was even placed on assignment on-site at the Boulder, Colorado NIST facility during the testing. In addition, GPS expert assistance was provided by Fort Huachuca (the DoD Electronic Proving Grounds) to create and execute the test plan.[20]

As directed by the DoD, the testing campaign itself was funded by Ligado under a cooperative research and development agreement (CRADA), the standard business approach used by many government agencies to enable the use of expensive government provided facilities and to help fund the government research activities. The NASCTN test plan was developed solely and independently by NIST personnel. It was designed to analyze the power and emission parameters in Ligado's December 2015 applications, and was published, widely reviewed by industry, government and associated organizations like the National Space-Based Positioning, Navigation and Timing Advisory Board (PNTAB) and numerous recommendations were received, carefully reviewed and as appropriate, incorporated into the test plan by the NIST personnel.[21]

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[20] Page v of NIST Technical Note 1952 LTE Impacts on GPS Final Report, Feb 2017

[21] "In this project, NASCTN developed a test method to investigate the impact of adjacent band LTE transmissions on GPS receivers in tracking and reacquisition modes." From paragraph 38 of FCC-20-48A1

Importantly, the NASCTN test plan was focused not only on the performance of the test itself, but also on the establishment of a standardized way of performing this kind of test. It was carefully performed to generate information for others to use to draw conclusions.

The NASCTN testing was performed using 14 devices from four categories of GPS Receiver, General Location, High Precision, GPS development boards, and Timing. The cellular device category was not tested since it was clear from the RAA test and other information that this device category was the least likely to experience any interference issues. The validity of this decision was later confirmed by the DOT ABC Study. The Timing category is particularly important since NIST knows more about timing than any other organization in the U.S, if not the world.

Collecting the test data required 1476 hours of in chamber test time and the NIST developed tests were performed by NIST researchers applying their world class metrology skills in their brand-new state of the art multi-million-dollar DoD / DoC funded Anechoic Chamber at the NIST facilities in Boulder, CO. (See Figure 1 below[22]). Devices were individually tested to insure no interference between the GPS devices themselves.

[22] Page 43 of NIST Technical Note 1952 LTE Impacts on GPS Final Report, Feb 2017

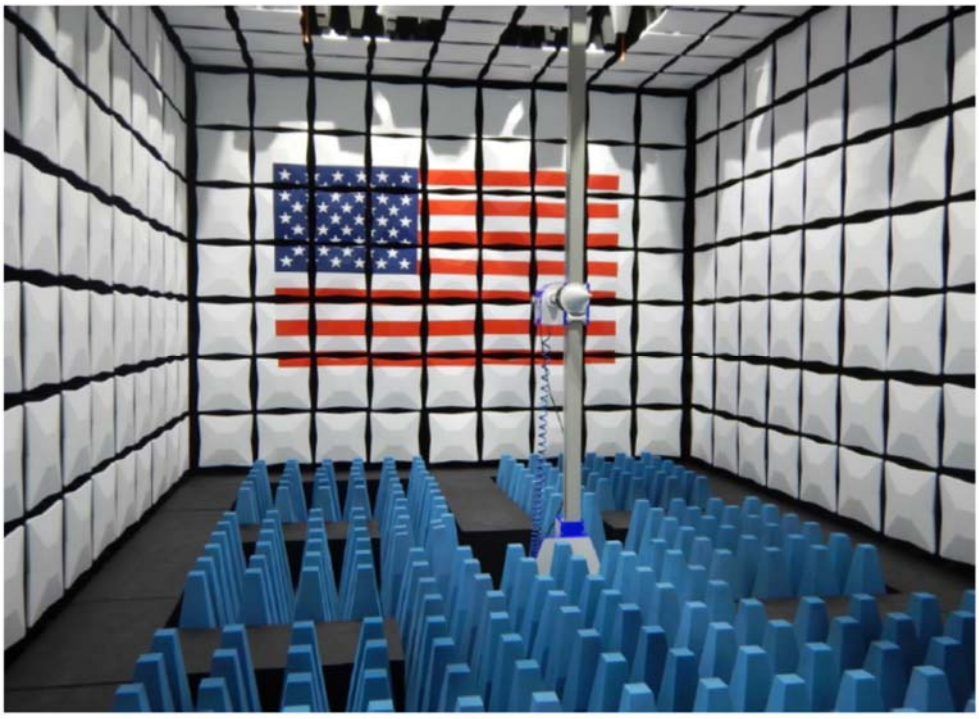

Figure 1. NASCTN Anechoic Chamber[23]

The NASCTN results, including raw data, was published and shared with both the FCC and NTIA. The metric for harm used in the study was consistent with the FCC definition of harmful interference, which is, does the device perform its intended function as would be expected by the user. The test also collected C/N_0 information for those devices that provided this information. In this regard, the NIST personnel noted that there are many algorithms available for estimating C/N_0, each of which provides slightly different results, and it wasn't clear which algorithms were used in which devices. Though the conclusions were left to those who analyzed the data, and not performed by the NIST personnel, the testing clearly

[23] Page 43 from Dr. William Young et al., NASCTN, *LTE Impacts on GPS: Final Test Report* (Feb. 15, 2017), https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1952.pdf *cited on* Page 21 of Ligado Ex Parte Filing June 5, 2017

showed that most of the devices were easily compatible with the current Ligado deployment proposal.[24]

Some High Precision GPS devices did experience observable interference at the levels expected of the 32 dBW deployments. (As noted above, this level was reduced to 9.8 dBW by the 2018 Amendment.) Testing confirmed that this was resolved by the addition of filtered antennas. All of the other classes of devices and especially timing devices worked flawlessly. Similarly, in tests for Time to First Fix (TTFF) on the GPS satellites, and Time to First Reacquisition (TTFR) demonstrated no issues in this area. Finally, no Loss of Lock issues were observed with any of the devices at the 32 dBW power level in the 2015 Application.

The third set of tests, known as the **GPS Adjacent Band Compatibility (ABC) Study,** was sponsored and funded by the Department of Transportation (DOT), with involvement from many government, commercial and private organizations. A test plan was published, reviewed and numerous recommendations were received from government agencies, advisory groups, Ligado, and the industry. These submissions specifically included requests for harmful interference related information since that is the regulatory criteria that the FCC, the expert Federal Government agency with the responsibility for the determination has always used to assess interference issues.[25] The request was to measure position data, which is the natural output of a GPS device. This request was ultimately rejected since the

[24] Paragraph 82 from FCC-20-48A1

[25] The lack of raw data is discussed in FCC 20-48A1 paragraph 54

DOT concluded that harmful interference was not the correct basis for assessing impact of the Ligado spectrum proposal on GPS devices.

The DOT ABC testing was performed in compliance with the 1 dB degradation Interference Protection Criteria (IPC) advocated by the PNTAB.[26] Another of the six criteria established by the PNTAB was openness, but the DOT Study did not adhere to that criteria since no outside observers were allowed for the tests; all results were taken by the vendors themselves, then strictly anonymized; and only worst-case device results at each frequency were publicly reported.[27] In addition, as noted above, the testing ignored the FCC's harmful interference assessment needs.

The DOT ABC test itself included 80 devices drawn from six categories of GPS receivers - General Location, High Precision, Cellular, Non-certified Aviation, Timing, and Space Based. Unlike the RAA and NASCTN tests, the DOT tests took place, as the Order correctly notes, in a "semi-anechoic" chamber.[28] Also unlike the RAA and NASCTN tests, where devices where tested individually in the NASCTN case, or in pairs in the RAA case, to prevent device-to-device interference, all 80 devices were tested at once -- as the Order correctly puts it, "as a 'batch'."[29] This was very efficient from a test time perspective for the DOT and the numerous vendors involved allowing for the collection of all the data in about one day. The DOT ABC study

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[26] Page 9 from https://ecfsapi.fcc.gov/file/10315464606940/RNT%20Foundation%20ex%20parte%20FCC%20-%20Ligado%20-%203%20editorials.pdf

[27] Id. Paragraph 54

[28] Id.

[29] Id.

strictly examined was whether the receiver "could experience a 1 dB degradation to the C/N_0 with respect to any satellite within view of the receiver (not necessarily limited to just those satellites used in the navigation solution). This 1 dB C/N_0 degradation metric does not assess whether the actual performance of the GPS devices is affected." The Order correctly determines that the DOT ABC test did not determine if any "harmful interference" would be experienced "as defined by the Commission."[30] The order also notes other deficiencies in the DOT ABC test such as:

> 54. We find that there are important deficiencies in the DOT ABC Report. The report only provided a summary of the data collected in the tests and did not provide the raw data that may have enabled some insight into the variation in the C/N0. Additionally, we note that there are other significant measurement uncertainties in the DOT ABC Report. For instance, 80 GPS receivers were tested simultaneously as a "batch" in a semi-anechoic chamber with all the devices illuminated by GNSS and LTE signals from fixed overhead antennas. This approach creates a unique propagation path and orientation relative to each receiver under test, thus varying gain levels with respect to both of the transmit antennas. The measurement uncertainties created by this approach were not quantified. In contrast, the RAA testing and the NASCTN Report implemented a sequential approach to performing measurements on each GPS receiver individually that ensured that consistent test conditions were maintained, thereby reducing the potential for measurement uncertainties."[31]

Figure 2 below shows the semi-anechoic test facility used for the DOT ABC test.

[30] Paragraph 48 of FCC-20-48A1
[31] Paragraph 54 from FCC-20-48-A1

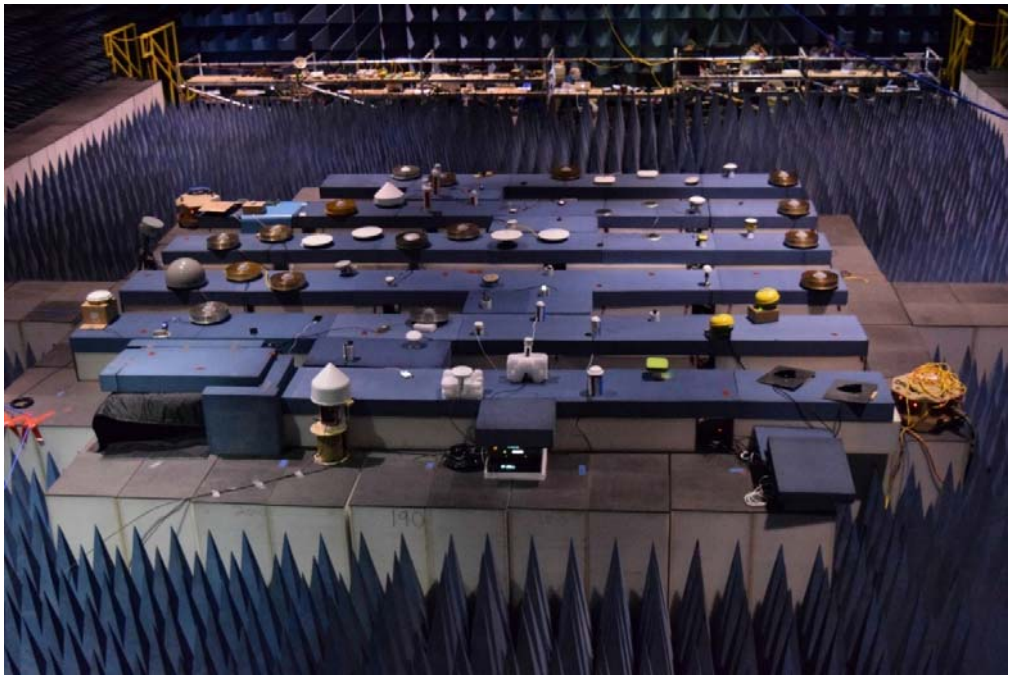

Figure 2. GPS/GNSS Receivers in WSMR Semi-Anechoic Chamber[32]

As noted in Mr. Ed Drocella's Declaration attached to the NTIA Petition for Reconsideration, FCC OET (Office of Engineering and Technology) staff participated in a Technical Focus Group (TFG) organized by Mr. Drocella along with other government stakeholders to review available test data collected. Therefore contrary to the contention of some of the Petitioners, when the FCC made its well-reasoned decision in the Order, they were very well-informed both on all the available test data that the NTIA and other government organization considered and analyzed, as well as all concerns from other government organizations.[33,34]

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[32] Page III of U.S. Department of Transportation, "Global Positioning System (GPS) Adjacent Band Compatibility Assessment," Final Report, at 118-19, 149, 152-53 (April 2018), https://www.transportation.gov/sites/dot.gov/files/docs/subdoc/186/dot-gps-adjacent-band-final-reportapril2018.pdf *cited on* Page 1 of Ligado May 31, 2018 Ex Parte

[33] "Specifically, OSM set up and I chaired a Technical Focus Group (TFG) within the Interdepartment Radio Advisory Committee (IRAC) to study the extensive amounts of available test data collected from several measurement studies involving a wide range of GPS receiver devices.

4 1 dB IS NOT A STANDARD, AND ALSO IS AN INAPPROPRIATE METRIC TO REGULATE SPECTRUM IN THIS CONTEXT

Contrary to the position of several Petitioners, the Order correctly finds a 1 dB metric "problematic and inappropriate."[35] The declaration attached to the NTIA Petition states, "NTIA has previously relied solely on a 1 dB reduction in C/N_0 as an interference protection criterion (IPC),"[36] and cites an NTIA letter as support.[37] The declaration also mentions that the NTIA began using 1 dB C/N_0 as criteria for GPS protection in 2012.[38] The referenced 2012 NTIA letter introduces 1 dB as a criteria for GPS protection and it in turn references ITU-R M.1903.[39] The ITU document discusses 1 dB C/N_0 as criteria for protecting GPS devices from equipment operating in the exact same band as GPS, and therefore does not support the usage of 1 dB C/N_0 as proposed by the NTIA for equipment operating in separate bands. Specifically, the 1 dB metric, (which has not been defined and thus is not a standard) does *not* support use of the criteria for out-of-band coexistence. To our

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Engineers from OSM, in collaboration with subject matter experts from the Department of Transportation (DoT), Federal Aviation Administration, the Air Force, the Department of Energy, the National Aeronautics and Space Administration, the Department of Defense Office of the Chief Information Officer, and the Federal Communications Commission's Office of Engineering and Technology, participated in the IRAC TFG." Ed Drocella sworn statement attached to page 33 of NTIA Petition for Reconsideration in Ligado Proceedings

[34] Paragraph 123 FCC 20-48A1

[35] Paragraph 100, from FCC-20-48A1

[36] from Ed Drocella sworn statement attached to page 33 of NTIA Petition for Reconsideration in Ligado Proceedings.

[37] See, e.g., NTIA Feb. 14, 2012 Letter to FCC at 4, available at https://go.usa.gov/xvSnn.

[38] See, e.g., NTIA Feb. 14, 2012 Letter to FCC at 4, available at https://go.usa.gov/xvSnn.

[39] See ITU-R M.1903 Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) and receivers in the aeronautical radionavigation service operating in the band 1559 – 1610MHz, available at https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1903-0-201201-S!!PDF-E.pdf

knowledge, neither the FCC, nor any other regulatory body in the world including the ITU, nor any international standard has ever used a 1 dB C/N_0 reduction as criteria for out-of-band co-existence.[40]

The Order points out that the GPS Interface Specification.[41], published by the GPS Directorate, indicates to users of the GPS Space Segment that they could expect a variation in the C/N_0 of approximately 2 dB due to the movement of the polar-orbiting GPS satellites across the field-of-view of a GPS receiver. In addition, NASCTN reported that there are multiple methods of calculating C/N_0, which can provide variability and disagreement in what constitutes a 1 dB change.

> "We also observe C/N_0 estimator inaccuracies from an examination of the available raw data collected in the NASCTN Report, which strongly suggest that the C/N_0 estimators are generally not capable of accurate and reliable detection of a 1 dB change in the noise power component of the C/N_0".[42]

The FCC correctly concludes in the Order that a 1 dB change in C/N_0 does not directly correlate with harmful interference, and that the FCC would rely on performance-based metrics for a determination of harmful interference.[43]

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[40] Paragraph 53 from FCC-20-48A1

[41] Global Positioning Systems Directorate Systems Engineering and Integration, Interference Specification IS-GPS-200, Navstar GPS Space Segment/Navigation User Interfaces, IS-GPS-200H, at 51-52, Sec. 6.3.1 Fig. 6-1 (illustrating an approximately 2 dB decrease in the received power at a GPS receiver's antenna due to an increase in the elevation angle of a GPS satellite from 40 degrees to 90 degrees or to a decrease from 40 degrees to 5 degrees) (Sept. 24 2013), https://www.gps.gov/technical/icwg/IS-GPS-200H.pdf ,.

[42] NIST Technical Note 1952 LTE Impacts on GPS Final Report, Feb 2017 (added underline)

[43] "47. Decision. After examining the record on testing, including the methodologies used for purposes of protecting GPS devices from potential harmful interference, we conclude that our evaluation of the receiver test data presented in the record will rely on performance-based metrics, and not on testing based on application of a 1 dB C/N0 degradation as a measurand employed by certain of the technical studies before us, as this does not assess and is not directly correlated with harmful interference." From FCC-20-48A1

The test results analyzed in the Order further show that antenna replacement is an effective mitigation approach. These tests show that replacing stock antennas with commercially available filtered antennas can greatly improve compatibility for affected high performance GPS devices.[44] The Order correctly notes that Ligado has committed to provide commercially available filtered antennas as one of several methods to mitigate any harmful interference experienced by high performance devices.[45]

The Chief of the Spectrum Engineering and Analysis Division in the Office of Spectrum Management (OSM) at the NTIA acknowledged in the NTIA Petition that filtered antennas can be efficacious to reduce interference and improve compatibility.[46]

In its Petition, Trimble highlighted that, "For example, of the devices RAA tested, one out of 12 general location/navigation receivers was impacted when applying the impaired GPS constellation configuration in a dynamic GPS scenario,

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[44] "The testing indicated that three of these devices became compatible with Ligado's proposed network by changing the stock-supplied antenna to a filtered antenna that provides improved adjacent-band rejection characteristics." From paragraph 80 of FCC-20-48A1 and "Also similar to the RAA testing, three high-precision receivers that had stock antennas replaced with a more spectrally efficient antenna were retested and showed a susceptibility improvement of 60-70 dB." From paragraph 81 of FCC-20-48A1

[45] "However, to address concerns about potential impact on U.S. Government devices, Ligado commits to specific mitigation measures, including the updating (e.g., retrofit with improved antennas), repair, or replacement of devices both pre-and post-deployment of Ligado's network." From paragraph 96 of FCC-20-48A1

[46] "However, to address concerns about potential impact on U.S. Government devices, Ligado commits to specific mitigation measures, including the updating (e.g., retrofit with improved antennas), repair, or replacement of devices both pre-and post-deployment of Ligado's network;" And "impacts to most HP and GLN devices would appear to be more likely when receiver bandwidth extends outside RNSS allocation (i.e., HP and GLN receivers with higher combined out-of-band filtering between 1530 MHz and 1550 MHz could be less susceptible to interference centered at 1530 MHz);" and "external antenna filter selectivity would be a contributing factor to the interference power level that causes degradations in C/N0;" from Ed Drocella declaration attached to NTIA Petition for Reconsideration in Ligado Proceedings

and an impact was observed for seven out of 11 high-precision receivers."[47] The quotes are seen to be taken out of context after looking at the complete paragraphs:

> "79. The *RAA testing found "no impact"[274] to the three cellular devices* in the presence of both the downlink and uplink channels of the modified ATC network.[275] *It also found no impact to general location/navigation (including non-certified aviation) devices*. It contends that the results show for all 12 general location/navigation devices there was no impact to 2D position accuracy relative to the baseline condition where no LTE signal is present when tested under the Open Sky constellation configuration under static GPS receiver conditions and with the LTE signal transmitting in the one downlink and two uplink channels.[276] *One general location/navigation receiver (a Garmin device) was impacted by the LTE uplink in the 1627.5-1637.5 MHz band when applying the impaired GPS constellation configuration in a dynamic GPS scenario, but the report concluded that this was an "extremely low probability" event.*[277] For the general non-certified aviation receiver tested, no impact was observed to the 2D position accuracy from the LTE transmission on any of the downlink or uplink channels.
>
> 80. The 11 high-precision receivers tested showed varying results. *Four high-precision devices showed no impact* (i.e., no 3D position error) in the presence of Ligado's modified ATC downlink and uplink signals relative to the baseline condition where no LTE signal is present.[278] There was an impact observed for the remaining seven high-precision receivers. They demonstrated an impact from the proposed 1526-1536 MHz downlink channel while transmitting at the maximum power level (32dBW). The 3D position accuracy of the receiver was impacted at various received power levels ranging between -24 dBm and -55 dBm.[279] *The testing indicated that three of these devices became compatible with Ligado's proposed network by changing the stock-supplied antenna to a filtered antenna* that provides improved adjacent-band rejection characteristics.[280] Upon retesting those high-precision devices with a more spectrally efficient antenna, they showed no impact.[281] Three of the remaining four impacted high-precision receivers used internal antennas that could not be replaced with a more spectrally-efficient antenna and were not retested. Three of the high-precision receivers also demonstrated an impact from the proposed 1627.5-1637.5 MHz uplink channel. However, the RAA testing indicated that two of the three devices that had experienced impacts were compatible after changing the stock GPS receive antenna to a more spectrally efficient one. They showed no impact upon further testing. The remaining impacted receiver was not retested with a filtered antenna (presumably because it used a stock antenna that could not be changed).[282]"[48] *(emphasis added)*

The Order correctly summarizes that High-Performance Devices experiencing interference will be far fewer than suggested by the above testing since they used 32

[47] Page 18 of Trimble – Petition for Reconsideration of Ligado Order

[48] Paragraph 79 and 80 from FCC – 20-48A1

dBW and not the 9.8 dBW level contained in the 2018 Amendment and included in the Order. The Order also correctly summarizes that High-Performance Devices can be made resilient with the addition of a commercially available filtered antenna.[49]

As has been well documented in the record and reflected in the Order, there is no domestic or international standard that relies on 1 dB C/N_0 degradation for compatibility with out-of-band signals. Finally, the long-accepted principle is that harmful interference is based on impairment of the functionality of an RF device.

The 1 dB C/N_0 degradation level relied on by its proponents is calculated internally, differently, and inconsistently for each GPS device model. The result is that for identical RF interference conditions, that is, for identical GPS and Ligado RF signal levels, different GPS devices produce widely different C/N_0 output readings. All the GPS tests conducted, the Roberson, NASCTN, and DOT tests included, clearly and unequivocally show this to be the case.[50,51]

If this method of 1 dB C/N_0 degradation (device based measurement) were to actually measure a 25% increase in the noise floor in the GPS band as claimed by its proponents (which for out-of-band signals it does not), then each and every GPS receiver would produce the same C/N_0 output for identical GPS and Ligado RF signal levels. Therefore, 1 dB C/N_0 is not a useful or useable metric for assessing harm for out-of-band emissions.

The Commission has correctly relied on GPS device functionality as the appropriate measure of compatibility with Ligado operations.

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[49] Paragraph 80 from FCC-20-48A1

[50] Appendix B from NIST Technical Note 1952 Feb 2017

[51] Paragraph 47 and 48, from FCC – 20-48A1

5 RESOLUTION OF IRIDIUM CO-EXISTENCE ANALYSIS CONCERNS

The Iridium Petition for Reconsideration[52] claims that the Order did not include adequate support for the OOBE (Out of Band Emissions) limits and dismissed three of Iridium's technical concerns. The OOBE limits were analyzed in detail during the development of the 2005 ATC Order.[53] In that examination a conservative analysis showed that the aggregate OOBE from 9 million terminals would not cause interference to MSS operators. Iridium claims that increasing the number of ATC users would simply linearly increase the aggregate OOBE interference. The current LTE and future 5G technologies assign users to specific sets of OFDM sub-carriers and specific allowed transmit time intervals. The individual users transmit power levels are reduced depending on the path loss from the base station to the user terminal. Ligado pointed out the conservative assumptions of the Iridium analysis and the importance of considering probabilistic effects.[54] Assuming all devices transmit continuously at full power is a misrepresentation of how LTE and 5G networks operate.

Iridium also raised the image of billions of IOT devices as a worst-case scenario.[55] This imagery ignores the way that LTE and 5G user devices are scheduled in time and frequency by the network and never all transmit simultaneously.[56,57]

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[52] Iridium Petition for Reconsideration
[53] ATC Report and Order, 2005
[54] Ligado Ex Parte re Iridium (Public 11-2-2016).pdf
[55] Page 9 of Iridium Petition for Reconsideration
[56] Page 47, section 2.6.1 of https://www.fcc.gov/ecfs/filing/60001486460

There are three specific technical concerns that Iridium claims were not addressed in the Order. The first concern is that the Order ignored Iridium's analysis because it was performed using a higher ATC device OOBE level than was finally approved in the Order. The Order specifically discusses Iridium's OOBE concerns in paragraphs 115 through 117 and notes that Iridium requested a reduction in the OOBE limit. The Order describes that the FCC did respond to OOBE interference concerns and did reduce the OOBE limit by 9 dB from -58 dBW/4KHz to -67 dBW/4KHz.[58]

The second Iridium technical concern is that the Order rejected the use of free space path loss in the Iridium analysis was too conservative. Iridium claims that 47 CFR 25.253 mandates the use of free space path loss for calculating power flux density. 47 CFR 25.253 only requires the use of free space path loss for calculation of power flux density at "the edge of all airport runways and aircraft stand areas" and "the water's edge of any navigable waterway".[59] 47 CFR 25.253 also requires the use of free space path loss in the calculation of intermodulation from base stations. These are special cases and primarily not those of interest for Ligado terrestrial usage modeling.

The third Iridium technical concern is that the Order concluded that the use of 18 simultaneous ATC devices per LTE base station was too conservative. The Order was actually concerned with both the number of devices and the path loss assumption taken together and how they are used to conservatively calculate

[57] Page 14, section 3.4 of https://ecfsapi.fcc.gov/file/60002112686.pdf
[58] Paragraph 116 FCC 20-48A1
[59] 47 CFR 25.253(d) and

aggregate OOBE interference. Assuming all device signals and their OOBE are at their maximum power levels and that all paths between ATC devices and Iridium terminals are line-of-sight is extremely conservative and not realistic. The order indicates that Iridium would be expected to be able to co-exist with interference from out-of-channel emissions at a level that has been permitted in the rules since 2005.[60]

Finally, Iridium claims the Order ignored concerns about AMS(R)S. The Order requires Ligado to resolve any interference issues with AMS(R)S[61].

6 USE OF MANUFACTURER AGREEMENTS BY THE FCC

The Order observes the existence of "co-existence" agreement with five major GPS equipment manufacturers and provides a detailed analysis of the Agreements between Ligado and the three major manufacturers – Garmin, Deere, and Trimble.[62] Trimble filed a Petition for Reconsideration, and objected to procedural, economic and test related topics and only to a limited degree discussed the agreements struck with Ligado. The Commission should cast a skeptical eye on Trimble's Petition in light of past statements from Trimble in the record, and shown in Attachment [A], in which Trimble expresses its view that "it supports Commission grant of those aspects of the Modification Applications set forth in Trimble's Agreement with Ligado (the "Agreed Licensing Conditions"), as an integrated

[60] Paragraph 117 FCC 20-48A1
[61] Paragraph 118 FCC 20-48A1
[62] Paragraph 26 and 31, FCC-20-38A1

package."[63] The Order rightly described in considerable detail the technical elements of the agreements that were struck with each of the three vendors. The description of the agreements was supplemented by relevant elaboration by individuals and groups with expertise in the area. Neither Garmin nor Deere had an opposition to Ligado's proposed operations in the 1526-1536 MHz (at 32 dBW not 9.8 dBW), 1627.5-1637.5 and 1646.5-1656.5 MHz frequency bands. [64,65] Trimble expressed in the record more than once that it had no issue with the use of either 1627.5-1637.5 or 1646.5-1656.5 MHz at the Ligado power levels and agreed to work with Ligado on the availability of the 1526-1536 MHz band based on the outcome of the planned DOT ABC study.[66] Similarly, Ligado struck cooperation agreements with NovAtel/Hexagon, Topcon, and received Leica support based on NovAtel's support.[67,68,69,70,71] Finally, the Order references as "particularly instructive" the Ex Parte from Septentrio, a producer of high-precision GPS Receivers, which describes its immunity to Ligado's use of the spectrum stating that

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[64] See Attachment A.

[64] P22, 96 Garmin agreement

[65] paragraphs 1 - 4 Deere Agreement

[66] 3-4. Trimble also did not oppose Ligado's proposed operations in the 1627.5-1637.5 MHz and 1646.5- 1656.5 MHz frequency bands. Trimble Agreement

[67] NovAtel Jun. 28, 2016 Ex Parte; Topcon Nov. 29, 2016 Ex Parte .

[68] NovAtel Jun. 28, 2016 Ex Parte at 1.

[69] Letter from Doug Smith, CEO, Ligado Networks LLC, and Ivan Di Federico, Chief Strategy Office, Topcon Positioning Systems, Inc. to Marlene H. Dortch, Secretary, FCC, IB Docket 11-109 (filed Nov. 29, 2016); TOPCON GNSS, https://www.topcon.co.jp/en/positioning/museum/gnss/; TOPCON HiPer VR, https://www.topconpositioning.com/gnss-and-network-solutions/integrated-gnss-receivers/hiper-vr.

[70] Hexagon May 7, 2018 Ex Parte at 1.

[71] Leica Geosystems June 28, 2016 Ex Parte. See generally GNSS Systems / Leica Geosystems, https://leicageosystems.com/en-us/products/gnss-systems (discussing Leica's GNSS-enabled devices).

Ligado' proposed services and operating parameters "fall within the type of interference GNSS receivers can be immune to by design."[72]

Quibbling about other matters in the Petition by Trimble do not detract from the well-documented relationships and mutual commitments that have been established between Ligado and each of the manufacturers. The Order therefore not only correctly quotes and characterizes these important documents from the world's leading producers of GPS Receivers, it rightly uses this information to inform the decision the Order documents.

7 CONCLUSION

An analysis of the petitions for reconsideration reveals no new information that would justify Commission action to revisit the Order and Authorization of Ligado's terrestrial service. As described in the Sections above, the various issues and concerns raised by the petitioners have already been thoroughly considered and carefully addressed in the Order. Therefore, the Petitions for Reconsideration are individually and collectively without merit and should be denied.

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[72] Letter from Neil Vancans, VP Global Sales, Septentrio, to Marlene H. Dortch, Secretary, FCC, IBFS Docket No. 11-109, IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091 (filed Oct. 9, 2018) (Septentrio Oct. 9, 2018 Ex Parte). See infra section III.D.1. We find that Septentrio's October 2018 ex parte submission is particularly instructive. Septentrio notes that GNSS receivers are inherently vulnerable to a variety of disturbances, whether naturally occurring or man-made. Septentrio Oct. 9, 2018 Ex Parte at 2. Septentrio states that its hardware is compatible with Ligado's proposed services and that its proposed operating parameters "fall within the type of interference GNSS receivers can be immune to by design. " Id . Septentrio states further that its high-end precision receivers "are designed and have proven to be robust in challenging RF environments, including with respect to adjacent band terrestrial operations." Id. Septentrio concludes that its receivers "need to be, not just to cope with Ligado's signals, but with the many other forms of accidental or structural signal transmissions adjacent to the GNSS bands."

Respectfully submitted,

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8 ATTACHMENT A

Quotations from Trimble Filings Expressing Support for Ligado's Applications

> ***We observed that Trimble has supported grant of the above-referenced applications for modification, except that it has not supported use of the 1526-1535 MHz band as described in those applications.***

Letter from Russell H. Fox, Counsel for Trimble Navigation Limited to Marlene Dortch, Secretary, FCC, IB Docket No. 12-340; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD 20101118-00239; SES-MOD-20121001-00872; LightSquared Technical Working Group, IB Docket No. 11-109; DA 16-442; IB Docket No. 17-16 (July 26, 2019), *available at* https://ecfsapi.fcc.gov/file/10726184316976/Ex%20Parte%20Letter%20--%20Meeting%20on%20July%2024%2C%202019%20(As-Filed)%207.26.19.pdf.

> ***As Trimble noted in its comments, it supports Commission grant of those aspects of the Modification Applications set forth in Trimble's Agreement with Ligado (the "Agreed Licensing Conditions"), as an integrated package.***

Reply Comments of Trimble Navigation Limited, IB Docket No. 12-340, IBFS File Nos. SAT-MOD-20120928- 00160; SAT-MOD-20120928-00161; SAT-MOD-20101118-00239; SES-MOD20121001-00872; IB Docket No. 11-109; DA 16-442 (June 21, 2016), *available at* https://ecfsapi.fcc.gov/file/10621299326090/Trimble%20Ligado%20PN%20Reply%20Comments.pdf.

> ***In each case, we reiterated Trimble's support for Commission grant of the applications for modification submitted by Ligado Networks, LLC ("Ligado") as stated in and consistent with terms set forth in the letter submitted by Ligado and Trimble on February 3, 2016 (the "February Letter").***

Letter from Russell H. Fox, Counsel for Trimble Navigation Limited to Marlene Dortch, Secretary, FCC, IB Docket No. 12-340; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD 20101118-00239; SES-MOD-20121001-00872; LightSquared Technical Working Group, IB Docket No. 11-109; DA 16-442 (June 8, 2016), *available at* https://ecfsapi.fcc.gov/file/60002098894.pdf.

> ***Trimble supports the adoption of the technical parameters and licensing conditions covering Ligado's licensed frequencies at 1627.5-1637.5 MHz and 1646.5-1656.5 MHz and the proposed limitations on operations in the 1545- 1555 MHz band, all as specified in the Modification Applications, as an integrated package and as further detailed in Trimble's agreement with Ligado, (referred to herein as the "Agreed Licensing Conditions").***

Comments of Trimble Navigation Limited, IB Docket No. 12-340, IBFS File Nos. SAT-MOD-20120928- 00160; SAT-MOD-20120928-00161; SAT-MOD-20101118-00239; SES-MOD20121001-00872; IB Docket No. 11-109; DA 16-442 (May 23, 2016), *available at* https://ecfsapi.fcc.gov/file/60002016415.pdf.

> ***We observed that Trimble has supported grant of the above-referenced applications for modification, except that it has not supported use of the 1526-1535 MHz band as described in those applications.***

Letter from Russell H. Fox, Counsel for Trimble Navigation Limited to Marlene Dortch, Secretary, FCC, IB Docket No. 12-340; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD 20101118-00239; SES-MOD-20121001-00872; LightSquared Technical Working Group, IB Docket No. 11-109; DA 16-442 (May 20, 2016), *available at* https://ecfsapi.fcc.gov/file/60001997164.pdf.

CERTIFICATE OF SERVICE

I, Dennis A Roberson, hereby certify that on this 1st day of June, 2020, I caused a copy of the foregoing Opposition to Petitions for Reconsideration or Clarification to be served on the following:

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