

**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, | ) | IB Docket No. 12-340                       |
| IBFS Files Nos. SAT-MOD-20120928-00160, -      | ) |                                            |
| 00161, SES-MOD-20121001-00872                  | ) |                                            |
|                                                | ) |                                            |
| New LightSquared License Modification          | ) | IB Docket No. 11-109; IB Docket No. 12-340 |
| Applications IBFS File Nos. SES-MOD-20151231-  | ) |                                            |
| 00981, SAT-MOD-20151231-00090, and SAT-        | ) |                                            |
| MOD-20151231-00091                             | ) |                                            |
|                                                | ) |                                            |
| Ligado Amendment to License Modification       | ) | IB Docket No. 11-109                       |
| Applications IBFS File Nos. SES-MOD-20151231-  | ) |                                            |
| 00981, SAT-MOD-20151231-00090, and SAT-        | ) |                                            |
| MOD-20151231-00091                             | ) |                                            |

**ORDER AND AUTHORIZATION**

**Adopted: April 19, 2020**

**Released: April 22, 2020**

By the Commission: Commissioner Carr issuing a statement; Commissioners Rosenworcel and Starks  
Concurring and issuing a Joint Statement.

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## I. INTRODUCTION

1. Today we draw to a close a 17-year old proceeding by granting Ligado Networks LLC’s (Ligado’s) mobile satellite services (MSS) license modification applications, as amended.<sup>1</sup> Our decision authorizes Ligado to deploy a low-power terrestrial nationwide network in the 1526-1536 MHz, 1627.5-1637.5 MHz, and 1646.5-1656.5 MHz bands that will primarily support Internet of Things (IoT) services. Our action provides regulatory certainty to Ligado, ensures adjacent band operations, including Global Positioning System (GPS), are sufficiently protected from harmful interference, and promotes more efficient and effective use of our nation’s spectrum resources by making available additional spectrum for advanced wireless services, including 5G.

2. Ligado’s amended license modification applications significantly reduce the power levels of its operations from its earlier proposals and commit Ligado to providing a significant guard-band in the MSS spectrum to further separate its terrestrial transmissions from neighboring operations in the Radionavigation-Satellite Service (RNSS) allocation. Based on the extensive record, we conclude that Ligado’s latest proposal—combined with the stringent conditions we adopt today—addresses harmful interference concerns with respect to GPS operating in the adjacent RNSS allocation,<sup>2</sup> as well as concerns with respect to MSS licensees’ operations in the L-band. In sum, we find it is in the public interest to grant the modification applications to facilitate the deployment of a low power terrestrial-based network in its licensed MSS spectrum.

<sup>1</sup> See generally Letter from Gerard J. Waldron, Counsel to Ligado, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, and Amendment to License Modification Applications (filed May 31, 2018) (Ligado May 31, 2018 *Ex Parte* and Ligado Amendment).

<sup>2</sup> As discussed in this proceeding, GPS-enabled devices use signals received from the U.S.-based GPS satellites operating under the RNSS allocation in the 1559-1610 MHz band to provide position, navigation, and timing (PNT) services. In recent years, GPS-enabled devices increasingly have been designed to also operate with Global Navigation Satellite System (GNSS) signals. As discussed below, in 2018 we authorized GPS-enabled devices that also operate with Galileo’s GNSS signals to operate in the United States. In today’s action, we also conclude that adjacent-band operations that include use of Galileo’s GNSS E1 signals in the same RNSS allocation in which GPS operates are sufficiently protected from harmful interference. See *infra* para. 90.

## II. BACKGROUND

3. We currently have before us Ligado's 2015 license modification applications,<sup>3</sup> as amended in 2018, and technical studies supplied by Ligado purporting to demonstrate that these modifications address harmful interference concerns relating to GPS and other providers' MSS operations. The genesis of this proceeding, however, dates back to 2003, when the Commission established rules to permit MSS licensees to seek authority to operate Ancillary Terrestrial Component (ATC) stations.<sup>4</sup> An ATC system consists of terrestrial base stations and mobile terminals licensed to the operator of an MSS system, which allow an MSS licensee to integrate ATC in their MSS networks for the purpose of filling-in gaps in the MSS coverage area, particularly in urban areas or inside buildings.<sup>5</sup>

### A. Ligado's MSS and MSS ATC Authorizations

4. Ligado is authorized to provide MSS in the 1525-1559 MHz and 1626.5-1660.5 MHz bands, with the lower band allocated for downlink transmissions (from MSS satellites to mobile earth stations) and the upper band for uplink transmissions (from mobile earth stations to MSS satellites).<sup>6</sup> In

<sup>3</sup> See Letter from Gerard J. Waldron, Counsel to New LightSquared, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340 and 11-109; IBFS File Nos. SAT-MOD-20120928-00160, SAT-MOD-20120928-00161, and SES-MOD-20121001-00872 and Attach., Applications, Description of Proposed Modification (filed Dec. 31, 2015) (Ligado Dec. 31, 2015 *Ex Parte* and Applications, Description of Proposed Modification).

<sup>4</sup> See *Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Bands; Review of the Spectrum Sharing Plan Among Non-Geostationary Satellite Orbit Mobile Satellite Service Systems in the 1.6/2.4 GHz Bands*, IB Docket Nos. 01-185 and 02-364, Report and Order and Notice of Proposed Rulemaking, 18 FCC Rcd 1962 (2003) (*ATC Report and Order*), modified by *Order on Reconsideration*, 18 FCC Rcd 13590 (2003), reconsidered in part in *Mem. Opinion and Order and Second Order on Reconsideration*, 20 FCC Rcd 4616 (2005) (*ATC Reconsideration Order*).

<sup>5</sup> *ATC Report and Order*, 18 FCC Rcd at 1975, para. 23. The U.S. Table of Allocations was revised to include U.S. footnote 380 (permitting ATC operations in specified MSS bands). *Id.* at 2075, para. 236 n.622. The Commission concluded that allowing MSS licensees to deploy these terrestrial networks would serve the public interest by increasing the MSS operator's network capacity, making more efficient use of spectrum, extending coverage to places where MSS operators have previously been unable to offer reliable service, improving emergency communications, and enhancing competition. *Id.* at 1973-89, paras. 19-45.

<sup>6</sup> The original MSS licensee and predecessor-in-interest to Ligado was AMSC Subsidiary Corporation (a subsidiary of the American Mobile Satellite Corporation). Since that time, as a result of a number of reorganizations, the licenses were held by different entities before being held by Ligado. For simplicity of exposition, we refer to Ligado Networks LLC and all of its predecessors-in-interest collectively as "Ligado." See *SkyTerra Application for Modification Authority for an Ancillary Terrestrial Component*, File Nos. SAT-MOD-20090429-00047, SAT-MOD-20090429-00046, SES-MOD-20090429-00536, *Call Sign AMSC-1*, *Call Sign S2358*, *Call Sign E980179*, Order and Authorization, 25 FCC Rcd 3043, 3044-45, para. 2 n.3 (IB Mar. 26, 2010) (*SkyTerra ATC Modification Order*); *Mobile Satellite Ventures Subsidiary LLC, Application for Minor Modification of Space Station License for AMSC-1*, File No. SAT-MOD-20031118-00333, File No. SAT-AMD-20031118-00332, File No. SES-MOD-20031118-01879, Order and Authorization, 19 FCC Rcd 22144 (IB 2004) (*2004 ATC Authorization Order*); *Motient Corp. and Subsidiaries, Transferors, and SkyTerra Communications, Inc., Transferee Application for Authority to Transfer Control of Mobile Satellite Ventures Subsidiary LLC*, WC Docket No. 06-106, Memorandum Opinion and Order and Declaratory Ruling, 21 FCC Rcd 10198 (IB Sept. 15, 2006); *SkyTerra Communications, Inc., Transferor and Harbinger Capital Partners Funds, Transferee Applications for Consent to Transfer of Control of SkyTerra Subsidiary, LLC*, IB Docket No. 08-184, Memorandum Opinion and Order and Declaratory Ruling, 25 FCC Rcd 3059 (IB Mar. 26, 2010) (*SkyTerra TOC Order*); *Applications of LightSquared Subsidiary LLC, Debtor-in-Possession, and LightSquared Subsidiary LLC For Consent to Assign and Transfer Licenses and Other Authorizations and Request for Declaratory Ruling on Foreign Ownership*, IB Docket No. 15-126, Memorandum Opinion and Order and Declaratory Ruling, 30 FCC Rcd 13988, 13990, para. 6 (2015); Press Release, Ligado Networks LLC, Ligado Networks Launches with Goal to Expand Delivery of Next-Generation Mobile Connectivity

(continued....)

2004, Ligado applied for and was granted authorization for ATC operations, which allowed it to deploy ATC, provided that it met the conditions required by the Commission's rules.<sup>7</sup> Since filing its initial application for ATC authority, and during subsequent modifications to its proposed ATC networks, Ligado has faced opposition from the GPS industry and others who express concern that Ligado's proposed terrestrial operations will interfere with existing GPS systems. The relevant stakeholders have periodically reached consensus on certain discrete issues, however, such as in 2004 with respect to out-of-band emissions (OOBE) limits that would protect GPS inside the RNSS allocation.<sup>8</sup>

5. In March 2010, Ligado applied for and was granted a waiver of certain of the ATC operating terms and conditions.<sup>9</sup> In November 2010, Ligado requested a modification of its ATC authorization to accommodate its plans to deploy a nationwide 4G satellite/terrestrial network under its ATC authority.<sup>10</sup> In January 2011, the International Bureau granted Ligado a waiver of the Commission's integrated service rule, modifying its ATC operations authorization conditioned on it addressing the GPS industry's interference concerns.<sup>11</sup> The *2011 Order and Authorization* established a working group (Technical Working Group) process wherein Ligado would work with the GPS industry, the National Telecommunications and Information Administration (NTIA), and other appropriate federal agencies to study the potential for overload interference to GPS devices and to identify any measures necessary to prevent "harmful interference" to GPS.<sup>12</sup> With a focus on Ligado's proposed terrestrial network, the

(Continued from previous page)

(Feb. 10, 2016), <https://ligado.com/press/ligado-networks-launches-with-goal-to-expand-delivery-of-next-generation-mobile-connectivity/>.

<sup>7</sup> See *2004 ATC Authorization Order*, 19 FCC Rcd at 22144, para. 1.

<sup>8</sup> See, e.g., Letter from Raul R. Rodriguez, Counsel to U.S. GPS Industry Council, to Marlene H. Dortch, Secretary, FCC, File Nos. SAT-MOD-20131118-00333, SAT-AMD-20131118-00332; SES-MOD-20031118-01879 (filed Mar. 24, 2004) (noting that Ligado (then Mobile Satellite Ventures Subsidiary LLC (MSV)) had worked with the U.S. GPS Industry Council to develop OOBE limits from MSV ATC base stations and terminals into the GPS band, which were "intended to protect GPS receivers and at the same time allow MSV to maximize the utility of its ATC services to its users."). The U.S. GPS Industry Council said MSV was "to be commended for its proposal to use its spectrum in a responsible manner that ensures the continued utility of GPS receivers operating in the vicinity of MSV ATC stations." *Id.*

<sup>9</sup> *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3043, para. 1. Ligado sought waiver of certain provisions of the ATC rules (i.e., the power limits for ATC base-station transmissions and base station OOBE limits) to substitute the more flexible technical requirements contemplated by the terms of a coordination arrangement it had negotiated with Inmarsat. *Id.* at 3046-47, paras. 9-11. Ligado's March 2010 modification request was limited to its coordination agreement with Inmarsat. *Id.* at 3046, para. 9.

<sup>10</sup> LightSquared Subsidiary LLC Request for Modification of its Authority for an Ancillary Terrestrial Component, SAT-MOD-20101118-00239 (filed Nov. 18, 2010) ("LightSquared ATC Modification Request"). Specifically, Ligado's November 2010 modification asserted that the services it planned to offer met the Commission's integrated service requirements for MSS/ATC for L-Band MSS systems contained at 47 CFR § 25.149(b)(4). See *LightSquared Subsidiary LLC Request for Modification of its Authority for an Ancillary Terrestrial Component*, SAT-MOD-20101118-00239, *Call Sign S2358*, Order and Authorization, 26 FCC Rcd 566, 566, para. 1 (IB Jan. 26, 2011) (*2011 Order and Authorization*)).

<sup>11</sup> *2011 Order and Authorization*, 26 FCC Rcd at 587, para. 43. Finding that Ligado had failed to satisfy the integrated service rule, the International Bureau treated Ligado's modification request as one for waiver. *Id.* at 579-80, paras. 24-28. The integrated service rule requires MSS ATC licensees to "offer an integrated service of MSS and MSS ATC," and applicants must affirmatively demonstrate that "the MSS ATC operator will use a dual-mode handset that can communicate with both the MSS network and the MSS ATC component to provide the proposed ATC service" or "[o]ther evidence establishing that the MSS ATC operator will provide an integrated service offering to the public." 47 CFR § 25.149(b)(4)(i) and (ii). In the *2011 Order and Authorization*, the International Bureau conditionally waived that requirement. *2011 Order and Authorization*, 26 FCC Rcd at 566, para. 1.

<sup>12</sup> *2011 Order and Authorization*, 26 FCC Rcd at 586, para. 41.

Technical Working Group was specifically tasked with issuing a report to “provid[e] recommendations on steps that can be taken going forward to permit broadband wireless services to be provided in the L-Band MSS frequencies and co-exist with GPS devices” and “identify[ ] near-term technical and operational measures that can be implemented to reduce the risk of overload interference to GPS devices.”<sup>13</sup> The International Bureau stated that it expected the GPS industry to work in good faith with Ligado to ameliorate the interference concerns.<sup>14</sup> The *2011 Order and Authorization* provided that “once the Commission, after consultation with NTIA, concludes that the harmful interference concerns have been resolved,” Ligado could commence terrestrial operations.<sup>15</sup> The Technical Working Group filed its technical report on June 30, 2011.<sup>16</sup> That report, which identified different categories of GPS receivers—cellular, general location/navigation, high-precision, timing, networks, space-based, and aviation receivers—failed to reach consensus on whether concerns about harmful interference to GPS had been resolved.<sup>17</sup>

6. In February 2012, NTIA submitted additional studies and expressed its continued concerns that Ligado’s operations would cause harmful interference to GPS operations.<sup>18</sup> NTIA concluded that, based on its independent analysis of the studies, at that time there was “no practical way to mitigate the potential interference” from Ligado’s then-planned nationwide mobile broadband network.<sup>19</sup> At the same time, however, NTIA stated that the interference concerns in this proceeding raised important spectrum management issues concerning the full use of the spectrum resource, and noted the need to “stri[k]e the right balance between interference caused by transmitters and the performance of

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<sup>13</sup> *2011 Order and Authorization*, 26 FCC Rcd at 586, para. 42.

<sup>14</sup> *Id.*

<sup>15</sup> *Id.* at 587, para. 43.

<sup>16</sup> Technical Working Group Final Report, IB Docket No. 11-109, SAT-MOD-20101118-00239 (filed Jun. 30, 2011) (TWG Final Report). The report included information on base station transmitter characteristics, categories of GPS devices and their “representative performance characteristics,” and test plans and procedures, as required under the *2011 Order and Authorization*. *2011 Order and Authorization*, 26 FCC Rcd at 586-87, para. 43. The working group included subgroups that examined seven categories of GPS receivers—aviation, cellular, general location/navigation, high-precision, timing, networks, and space-based receivers. Trimble Navigation Limited (Trimble), Garmin International, Inc. (Garmin), and Deere & Company (Deere) were active participants in the working group process. The working group participants (Ligado, the GPS industry, wireless providers, aerospace/aviation companies, local and federal agencies, and others) did not always agree on the testing methodology and analyses, or how best to interpret the results with respect to potential interference. *See generally* TWG Final Report.

<sup>17</sup> *See* TWG Final Report at § 2.7.3.

<sup>18</sup> Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dept. of Commerce, to Julius Genachowski, Chairman, FCC, IB Docket No. 11-109 (filed Feb. 14, 2012) (NTIA Feb. 14, 2012 Letter). These additional studies included: the “Cellular Device Test Report”; the study requested by NTIA prepared by the National Space-Based Positioning, Timing Systems Engineering Forum (NPEF) (“Follow-on Assessment of LightSquared Ancillary Terrestrial Component Effects on GPS Receivers”); and the Federal Aviation Administration’s “Status Report Assessment of Compatibility of Planned LightSquared Ancillary Terrestrial Component Transmissions in the 1526-1536 MHz Band with Certified Aviation Receivers.” Citing the study on cellular phones that it submitted, NTIA concluded that Ligado’s proposed downlink operations at 1526-1536 MHz “does not significantly impact GPS receivers used in cellular devices.” *Id.* at 3. As for certified aviation receivers, NTIA noted that the FAA and Ligado had worked together in 2011 to try to resolve the impacts but had not found a practical solution. *Id.* at 5-6. In July 2011, NTIA had submitted an earlier study by NPEF on its testing. Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dept. of Commerce, to Julius Genachowski, Chairman, FCC, IB Docket No. 11-109 (filed July 6, 2011) (attaching study).

<sup>19</sup> NTIA Feb. 14, 2012 Letter at 1.

GPS receivers.”<sup>20</sup> NTIA “urge[d] the FCC, working with all stakeholders, to explore appropriate actions to mitigate against the impact GPS and other receivers may have to prevent the full utilization of spectrum to meet the nation’s broadband needs.”<sup>21</sup>

7. In the fall of 2012, Ligado again filed applications to modify its ATC authorization, this time with a provision that would limit its downlink operations to the lower 1526-1536 MHz portion of its MSS band (1525-1559 MHz).<sup>22</sup> This would effectively create a more than 20-megahertz guard-band in the MSS spectrum between its terrestrial transmissions and GPS operations in the RNSS spectrum allocation (1559-1610 MHz). Ligado also voluntarily committed not to deploy terrestrially in the 1526-1536 MHz portion of its MSS downlink band during the pendency of a rulemaking proceeding that it had requested to develop revised rules for terrestrial operations in that spectrum.<sup>23</sup> With respect to its proposed terrestrial wireless user equipment operations in the MSS uplink band, Ligado indicated that it planned to operate in the 1627.5-1637.5 MHz and 1646.7-1656.7 MHz portions of its MSS uplink band under the parameters of its existing 2010 ATC authorization (i.e., 0 dBW peak EIRP).<sup>24</sup> In December 2012, the International Bureau, the Office of Engineering and Technology, and the Wireless Telecommunications Bureau (the Bureaus) tolled the specific geographic measures and dates of the terrestrial build-out conditions placed on Ligado’s MSS L-Band license and related ATC authorization. The Bureaus found that such tolling would be in the public interest “until further determinations are made with respect to [Ligado]’s ATC authority.”<sup>25</sup>

8. In July 2013, Ligado submitted a report on its proposed use of terrestrial wireless user equipment within the MSS uplink band, including technical analyses of the potential interaction of these devices with GPS devices.<sup>26</sup> Representatives of the GPS industry—including Trimble, Garmin, and Deere through the GPS Innovation Alliance—again expressed concern about potential interference from

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<sup>20</sup> NTIA Feb. 14, 2012 Letter at 6.

<sup>21</sup> *Id.* at 7.

<sup>22</sup> Modification Application of LightSquared Subsidiary LLC, IBFS File Nos. SAT-MOD-20120928-00160, SAT-MOD-20120928-00161, and SES-MOD-20121001-00872 (filed Sept. 28, 2012 and Oct. 1, 2012 with identical narrative text) (2012 Modification Application Narrative). Specifically, Ligado proposed to permanently relinquish its authority to deploy terrestrial downlink operations at 1545-1555 MHz. 2012 Modification Application Narrative at 2, 10.

<sup>23</sup> 2012 Modification Application Narrative at 2. On September 28, 2012, Ligado filed its petition for rulemaking on the operating parameters of terrestrial use of the 1526-1536 MHz band, which indicated that the rulemaking could resolve interference concerns that would allow LightSquared to deploy its network using that spectrum. LightSquared Subsidiary LLC Petition for Rulemaking to Revise the Commission’s Technical Rules, RM-11683 (filed Sept. 28, 2012). Ligado withdrew this petition on February 8, 2016. Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 10-142; IB Docket Nos. 12-340 and 11-109; IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091; RM-11681 (filed Feb. 8, 2016).

<sup>24</sup> 2012 Modification Application Narrative at 4.

<sup>25</sup> *LightSquared Subsidiary LLC, Request for Relief from Build-Out Conditions*, IB Docket No. 12-296, Order, 27 FCC Rcd 15882, 15882, para. 1 (IB, OET, WTB 2012) (2012 Tolling Order).

<sup>26</sup> Letter from John P. Janka, Counsel for LightSquared Subsidiary LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340 and 11-109; IBFS File Nos. SAT-MOD-20120928-00160, SAT-MOD-20120928-00161, SAT-MOD-20101118-00239, and SES-MOD-2009/05121001-00872; RM-11681; WT Docket No. 12-327 (filed Jul. 15, 2013). The FCC sought comment on this report. *See Comments Sought on LightSquared Subsidiary LLC Ex Parte Filing*, Public Notice, IB Docket Nos. 12-340, 11-109; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD20101118-00239; SES-MOD-20121001-00872; RM-11681; WT Docket No. 12-327, 28 FCC Rcd 11764 (Aug. 7, 2013).

the proposed operations.<sup>27</sup> In July 2014, NTIA noted that federal agencies were not in complete agreement that Ligado's assessments had adequately addressed concerns of interference from these operations, and it also cited the concerns raised by the GPS Innovation Alliance.<sup>28</sup>

**B. Ligado's 2015 License Modification Applications and the Agreements with GPS Device Manufacturers**

9. On December 31, 2015, Ligado filed satellite modification applications in which it proposed new modifications to its proposed operational parameters (a combined set of both power limits and emissions limits) for its terrestrial wireless operations.<sup>29</sup> Specifically, Ligado proposed to abandon its authority for terrestrial operations in the 1545-1555 MHz portion of the MSS downlink band,<sup>30</sup> and to operate in three other L-band segments—base stations in the 1526-1536 MHz portion of the MSS downlink band and user equipment in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz portions of the MSS uplink band—under more restrictive operational parameters, including newly proposed OOBE limits.<sup>31</sup> Ligado stated that its abandonment of the use of the 1545-1555 MHz portion of the MSS L-band downlinks for terrestrial operations addressed a critical concern of the GPS industry, and that, when considered with other features, Ligado's proposal effectively provided GPS receivers operating in the 1559-1610 MHz RNSS band with a "significant guard band" from Ligado's terrestrial services that now would be restricted to the 1526-1536 MHz portion of the MSS L-band. Ligado further asserted that approval of its proposals as license conditions addressed the "core concerns" that had earlier been raised by the GPS industry in these proceedings.<sup>32</sup> Ligado stated that these conditions were the result of

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<sup>27</sup> See, e.g., GPS Innovation Alliance Comments, IB Docket Nos. 12-340 and 11-109; WT Docket No. 12-327 (filed Sept. 6, 2013). Since issuance of the TWG Final Report in June 2011, Trimble, Garmin, and Deere each have filed a number of comments opposing the nationwide high-powered terrestrial network proposed by Ligado in 2011.

<sup>28</sup> Letter from Karl B. Nebbia, Associate Administrator, Office of Spectrum Management, NTIA, to Julius P. Knapp, Chief, Office of Engineering and Technology, FCC, IB Docket Nos. 12-340 and 11-109; IBFS File Nos. SAT-MOD-20120928-00160, SAT-MOD-20120928-00161, SAT-MOD-20101118-00239, and SES-MOD-20121001-00872; RM-11681; WT Docket No. 12-327 (filed July 1, 2014). The NTIA letter attached a letter from the Department of Transportation (DOT) expressing its concerns about possible effects on GPS, including concerns about the handset proposal and its underlying assumptions. *Id.*

<sup>29</sup> See generally Letter from Gerard J. Waldron, Counsel to New LightSquared, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340 and 11-109; IBFS File Nos. SAT-MOD-20120928-00160, SAT-MOD-20120928-00161, and SES-MOD-20121001-00872 and Attach., Applications, Description of Proposed Modification and Public Interest Statement (filed Dec. 31, 2015) (Ligado Dec. 31, 2015 *Ex Parte* or Applications, Description of Proposed Modification). With the filing of the Applications, Ligado withdrew its 2012 ATC modification applications in IB Docket No. 12-340. Ligado Dec. 31, 2015 *Ex Parte* at 1 and Attach., Technical Operating Parameters Specified in Coexistence Plans.

<sup>30</sup> In its 2012 modification applications Ligado had similarly proposed to permanently relinquish its authority to conduct terrestrial operations in the 1545-1555 MHz band. 2012 Modification Application Narrative at 2, 10.

<sup>31</sup> Applications, Description of Proposed Modification at 4-7 (setting forth the particular technical details of the proposal). We note that Ligado's proposed 2015 modifications with respect to the power limits generally involved the same levels (32 dBW equivalent isotropically radiated power (EIRP) in the downlink band and -7 dBW in the uplink band) that were used in previous studies beginning in 2011. Applications, Description of Proposed Modification at 6.

<sup>32</sup> Ligado Dec. 31, 2015 *Ex Parte* at 1-2; Applications, Description of Proposed Modification at 3. Ligado states that these concerns do not include any concerns relating to cellular devices; it notes that the vast majority of GPS devices in use today are found in smartphones, and states that the mobile phone industry has not suggested that Ligado's operations were incompatible with smartphones. *Id.* at 3.

agreements that Ligado has reached separately with three major GPS device manufacturers—Deere<sup>33</sup> and Garmin,<sup>34</sup> prior to filing the modification applications, and Trimble<sup>35</sup> subsequent to the filing—that resolved concerns that each previously had raised in these proceedings regarding the potential incompatibility between GPS receivers and Ligado’s proposed operations in the MSS L-band.<sup>36</sup>

10. Ligado further proposed that concerns relating specifically to the aviation sector’s use of GPS be addressed by a separate license condition. Ligado committed to address the aviation community’s concerns by working with the Federal Aviation Administration (FAA) and the Radio Technical Commission for Aeronautics (RTCA) to ensure that compatibility would be achieved.<sup>37</sup> In particular, to protect certified aviation GPS devices, Ligado proposed that its license be conditioned on power limitation requirements for operation in the 1526-1536 MHz band as necessary to achieve compatibility with current and future Minimum Operational Performance Standards (MOPS) that are incorporated into an active Technical Standard Order (TSO) from the FAA.<sup>38</sup>

11. On April 22, 2016, the Bureau issued a Public Notice seeking comment on Ligado’s proposed license modification applications, including the specific components of the proposed operational parameters and the proposed license conditions.<sup>39</sup> In particular, the Public Notice sought comment on:

- the specifics of Ligado’s proposal relating to its proposed operations in the 1526-1536 MHz portion of the MSS downlinks (with power levels up to 32 dBW) and its abandonment of any terrestrial authorization in the 1545-1555 MHz portion;
- its modified proposals with respect to operating user equipment in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz portions of the MSS uplink band;
- the significance of the agreements between Ligado and Deere, Garmin, and Trimble; and
- whether the proposed set of operational parameters for operations in the 1526-1536 MHz, 1627.5-1637.5 MHz, and 1646.5-1656.5 MHz bands, along with the proposed license conditions, effectively resolved any interference concerns relating to GPS that previously had been identified.<sup>40</sup>

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<sup>33</sup> Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed Dec. 8, 2015) (attaching agreement) (Ligado Dec. 8, 2015 *Ex Parte* and Deere Agreement).

<sup>34</sup> Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed Dec. 17, 2015) (attaching agreement) (Ligado Dec. 17, 2015 *Ex Parte* and Garmin Agreement).

<sup>35</sup> Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed Feb. 3, 2016) (attaching agreement) (Ligado Feb. 3, 2016 *Ex Parte* and Trimble Agreement).

<sup>36</sup> Ligado Dec. 31, 2015 *Ex Parte* at 2 (discussing Deere and Garmin Agreements); Ligado Feb. 3, 2016 *Ex Parte*, Letter Attach. at 1 (joint statement by New LightSquared and Trimble states that the agreement involves an integrated package of recommendations “to resolve pending policy issues involving LightSquared spectrum”).

<sup>37</sup> Ligado Dec. 31, 2015 *Ex Parte* at 2, 4.

<sup>38</sup> Applications, Description of Proposed Modification at 10-12.

<sup>39</sup> *Comment Sought on Ligado’s Modification Applications*, Public Notice, IB Docket Nos. 11-109 and 12-340, 31 FCC Rcd 3802, 3802-03 (IB, OET, WTB 2016) (2016 *Comment PN*).

<sup>40</sup> *Id.* at 3808-09.



The Public Notice expressly sought comment on the potential for Ligado's proposed ATC network to cause "harmful interference" (as defined under the Commission's rules) to GPS receivers.<sup>41</sup>

12. *Agreements with additional GPS device manufacturers.* In May and June 2016, in response to Ligado's 2015 license modification applications, GPS device manufacturers NovAtel Inc. (NovAtel) and Topcon Positioning Systems, Inc. (Topcon) expressed concerns about potential harmful interference to their GPS devices.<sup>42</sup> In addition, four companies that rely on GPS devices filed comments agreeing with NovAtel's position.<sup>43</sup> Later in 2016, however, both NovAtel and Topcon entered into their own agreements with Ligado and indicated their support for Ligado's proposed operations.<sup>44</sup> Following NovAtel's decision to support Ligado's proposal, Leica Geosystems (Leica), one of the companies that earlier had agreed with NovAtel's initial concerns, also indicated its support for Ligado's proposal.<sup>45</sup> In May 2018, Hexagon Positioning Intelligence (Hexagon), another GPS device manufacturer, filed an *ex parte* indicating that it, too, had reached agreement with Ligado.<sup>46</sup>

13. *Reports assessing potential interference to GPS.* Following Ligado's 2015 license modification applications, three studies examining potential interference concerns relating to Ligado's proposed terrestrial operations and GPS device operations were conducted and incorporated into the record. First, in May and June 2016, Ligado filed reports on testing of GPS devices authored by Roberson and Associates (collectively the RAA Reports).<sup>47</sup> Second, in February 2017, Ligado also incorporated into the record a report on testing of GPS devices conducted by National Advanced Spectrum and Communications Test Network (NASCTN), titled "LTE Impacts on GPS Final Report"

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<sup>41</sup> 2016 Comment PN, 31 FCC Rcd at 3909 (citing the definition of "harmful interference" in 47 CFR § 2.1(c)).

<sup>42</sup> See generally NovAtel May 19, 2016 Letter Comments; Topcon May 23, 2016 Comments; Topcon June 20, 2016 Reply.

<sup>43</sup> Leica Geosystems May 26, 2016 Comments at 2 (endorsing NovAtel's May 19, 2016 Letter Comments); Agco June 6, 2016 Comments at 1 (same); Phoenix Aerial Systems Comments at 1 (same); Veripos Comments at 1 (same). See also Stephen M. Browne Comments (also supporting NovAtel's May 19, 2016 Letter Comments). We note that u-blox, a GNSS component manufacturer, also expressed its own concerns that GPS products using original equipment manufacturer (OEM) components may be adversely affected by Ligado's proposed operations. u-blox June 15, 2016 Reply at 1-2.

<sup>44</sup> Letter from Doug Smith, Ligado Networks LLC and Michael Ritter, NovAtel Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 and 12-340 (filed June 27, 2016) (NovAtel June 27, 2016 *Ex Parte*); Letter from Doug Smith, CEO, Ligado Networks LLC and Ivan Di Federico, Chief Strategy Officers, Topcon Positioning Systems, Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed Nov. 29, 2016) (Topcon Nov. 29, 2016 *Ex Parte*).

<sup>45</sup> Letter from Ken Mooyman, President, Leica Geosystems Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 and 12-340, at 1 (filed June 28, 2016) (Leica Geosystems June 28, 2016 *Ex Parte*).

<sup>46</sup> Letter from Michael Ritter, President, Hexagon Positioning Intelligence, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 and 12-340, RM-11681 (filed May 7, 2018) (Hexagon May 7, 2018 *Ex Parte*).

<sup>47</sup> See Roberson and Associates, Results of GPS and Adjacent Band Co-Existence Study (May 9, 2016) (May 2016 RAA Report), attached to Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, and Dustin Cho, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed May 11, 2016) (Ligado May 11, 2016 *Ex Parte*); Roberson and Associates, Final Report: GPS and Adjacent Band Co-Existence Study (June 10, 2016) (June 2016 RAA Report), attached to Letter from Gerard J. Waldron, Counsel to Ligado Networks, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed June 10, 2016) (Ligado June 10, 2016 *Ex Parte*). The June 2016 RAA Report "provid[es] supplemental details of the specific test procedures used to execute the test plan" described in the May 2016 RAA Report. June 2016 RAA Study at 5. The May 2016 RAA Report and June 2016 RAA Report are referred to collectively as the RAA Reports.

(NASCTN Report),<sup>48</sup> which Ligado had commissioned.<sup>49</sup> And third, Ligado's 2018 amendment incorporated into the record DOT's April 2018 "Global Positioning System (GPS) Adjacent Band Compatibility Assessment Final Report" (DOT ABC Report), wherein DOT tested GPS and GNSS devices and provided its assessment of the maximum transmitted power levels of adjacent band radiofrequency systems that could be tolerated by GPS and GNSS receivers that operate in the 1559-1610 MHz RNSS band.<sup>50</sup> The DOT ABC Report has two primary components, one led by the DOT Office of the Assistant Secretary for Research and Technology (OST-R), and the other led by the FAA.<sup>51</sup> OST-R's component focused on civilian GPS and GNSS devices and their applications, apart from certified aviation; the FAA's component focused on certified GPS aviation equipment standards.<sup>52</sup> In addition, the Resilient Navigation and Timing Foundation submitted into the record the March 2018 National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF) "Gap Analysis," which offers an assessment of testing methodologies that had been used in these three reports (as well as earlier testing).<sup>53</sup>

14. *Ligado's efforts to work with the FAA/RTCA to address certified aviation receivers.* Following submission of its 2015 license modification applications, Ligado worked with the FAA and that agency's advisory panels for more than a year to develop an approach to ensure that Ligado's operations protected certified aviation GPS receivers, including helicopter operations. In the fall of 2016, Ligado submitted its proposal to RTCA regarding Ligado's operations, including proposing a significant reduction of the power of its base station transmitters (and use of a "standoff cylinder" approach<sup>54</sup>); it also proposed to notify the FAA of the location of base stations in advance of any transmission.<sup>55</sup>

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<sup>48</sup> National Advanced Spectrum and Communications Test Network (NASCTN) Report, "LTE Impacts on GPS, Final Report" (February 2017), NIST Technical Note 1952, <https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1952.pdf> (NASCTN Report). See Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, RM-11681, at 2 (filed Feb. 24, 2017) (discussing the NASCTN Report and providing an electronic link to the complete report) (Ligado Feb. 24, 2017 *Ex Parte*).

<sup>49</sup> See Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, RM-11681 (filed Feb. 21, 2017) (discussing results of NASCTN Report); Ligado Feb. 24, 2017 *Ex Parte* at 2 (same); see also NASCTN Report at vii (noting that Ligado had submitted a project proposal to NASCTN in April 2016).

<sup>50</sup> 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> (DOT ABC Report); see Ligado May 31, 2018 *Ex Parte* at 1 (discussing the DOT ABC Report and providing an electronic link to the complete report).

<sup>51</sup> DOT ABC Report at 17.

<sup>52</sup> *Id.*

<sup>53</sup> See National Space-Based Positioning, Navigation and Timing National Systems Engineering Forum, Final Report: Assessment to Identify Gaps in Testing of Adjacent Band Interference to the Global Positioning System (GPS) L1 Frequency Band 3 (Mar. 1, 2018), attached to Letter from Dana A. Goward, President, Resilient Navigation and Timing Foundation to The Hon. Ajit Pai, Chairman, FCC, *et al.*, IB Docket Nos. 11-109 and 12-340 (filed Mar. 19, 2018) (NPEF Gap Analysis and Resilient Navigation and Timing Foundation March 19, 2018 *Ex Parte*). The other testing it analyzed included the 2011 Technical Working Group report and NPEF testing in 2011. *Id.*

<sup>54</sup> Ligado claims that through extensive work with the FAA, it developed the "standoff cylinder," which constitutes "a cylinder of airspace immediately adjacent to a Ligado antenna, extending 250 feet laterally from the antenna, and from the ground to 30 feet above the antenna." See Ligado June 5, 2017 *Ex Parte*, Attach. at 10-11. Ligado claims that it based this measurement in part on the FAA's requirement that operations closer than 500 feet from a person

(continued....)

### C. Ligado's 2018 Amended License Modification Applications

15. As a result of its collaboration with the FAA, Ligado, on May 31, 2018, filed an amendment to its 2015 license modification applications.<sup>56</sup> Specifically, Ligado proposed that the Commission authorize Ligado's ATC downlink terrestrial operations at 1526-1536 MHz subject to the following conditions:

- requiring that Ligado's ATC base stations operating at 1526-1536 MHz band not exceed an equivalent isotropically radiated power (EIRP) of 9.8 dBW (10 W) with a +/- 45 degree cross-polarized base station antenna;<sup>57</sup>
- prohibiting any Ligado ATC base station antenna in the 1526-1536 MHz band from operating at a location less than 250 feet laterally or less than 30 feet below an obstacle clearance surface established by the FAA;<sup>58</sup> and
- requiring Ligado to comply with specific reporting, notification, and monitoring obligations.<sup>59</sup>

In addition, Ligado said that it was "committed to providing specific mitigation measures (including but not limited to upgrading or replacing government devices) to address concerns about potential impact on U.S. Government devices, and it expects a requirement to this effect."<sup>60</sup>

16. Ligado stated that this amendment fulfilled its commitment in its 2015 license modification applications to limit the power in the 1526-1536 MHz portion of the MSS downlink band to levels necessary to achieve compatibility with current or future standards developed by the FAA to protect certified aviation GPS receivers.<sup>61</sup> In addition, Ligado contended that the proposed 9.8 dBW (approximately 10 Watts) base station power level (which is more than a 99.3% reduction from the 32 dBW (approximately 1585 Watts) maximum EIRP proposed in its 2015 license modification application) would benefit all GPS receivers and that Ligado's co-existence agreements with major GPS device manufacturers and the extensive empirical testing of other GPS receivers assured protection of all other classes of GPS devices.<sup>62</sup>

17. The Commission received numerous comments in response to Ligado's 2018 amended license modification applications. In December 2019, NTIA submitted a letter stating that, based on the assessments of the potential impacts of Ligado's proposal (including the most recent technical studies), federal agencies have significant concerns regarding the potential impacts, and further that, despite

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or object should be conducted with extreme care. Ligado June 5, 2017 *Ex Parte*, Attach. at 26. Ligado proposed that airspace outside of the standoff cylinder would be protected for certified aviation GPS receivers by ensuring that the received signal from Ligado's transmit power did not exceed the MOPS incorporated into active TSOs. Ligado June 5, 2017 *Ex Parte*, Attach. at 25-26. Ligado also committed not to install an antenna in a location where any portion of the standoff cylinder would enter the obstacle clearance surface. Ligado June 5, 2017 *Ex Parte* at 11.

<sup>55</sup> Ligado June 5, 2017 *Ex Parte*, Attach. at 10-11, 25-29.

<sup>56</sup> See Ligado May 31, 2018 *Ex Parte* and Ligado Amendment.

<sup>57</sup> Ligado May 31, 2018 *Ex Parte* at 1 (citing DOT ABC Report at 118-19, 149, 152-53) (concluding EIRP limit of 9.8 dBW (10W) at 1531 MHz will protect certified aviation receivers installed in helicopters operating in accordance with applicable existing MOPS).

<sup>58</sup> *Id.* at 2.

<sup>59</sup> *Id.*

<sup>60</sup> *Id.*

<sup>61</sup> *Id.* at 1.

<sup>62</sup> *Id.*, Ligado Amendment at 5.

considerable efforts to find a satisfactory solution, NTIA is unable to recommend the Commission's approval of the Ligado applications.<sup>63</sup> On April 10, 2020, NTIA submitted another letter, along with supplemental materials for the Commission's consideration (two letters from DOD and an Air Force memorandum endorsed by several federal agencies). In its letter, NTIA states that it believes that the Commission "cannot reasonably reach" a conclusion that harmful interference concerns relating to Ligado's proposed ATC operations have been resolved.<sup>64</sup>

### III. DISCUSSION

18. Based on our extensive review of the record, we conclude that grant of Ligado's ATC authorization, as proposed in 2015 and amended in 2018, with several additional conditions, is in the public interest. First, we find that there are significant public interest benefits associated with Ligado's proposed ATC network and deployment. Given other parties' concerns with Ligado's proposal, we then consider the record and concerns raised regarding potential harmful interference to adjacent band operations, including certified aviation GPS receivers and non-certified GPS receivers, as well as potential impact to U.S. Government devices. We then review concerns about harmful interference to MSS operations from the proposed ATC operations. We next impose conditions on Ligado's ATC authority to ensure Ligado will address any identified potential harmful interference to GPS and MSS operations before ATC network operations commence. In sum, we conclude that granting Ligado's amended license modification applications will promote the efficient and effective use of our nation's spectrum resources.<sup>65</sup>

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<sup>63</sup> Letter from Douglas W. Kinkoph, Deputy Assistant Secretary for Communications and Information (Acting), National Telecommunications and Information Administration, U.S. Dept. of Commerce, to Ajit Pai, Chairman, FCC, IB Docket No. 11-109 (filed Dec. 6, 2019) (NTIA Dec. 6, 2019 Letter), at 2. As part of its submission, NTIA enclosed three letters – a 2018 letter to NTIA from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM) and two letters submitted by DOD to the Commission in 2019. *Id.*, Enclosures 1-3.

<sup>64</sup> Letter from Douglas W. Kinkoph, Associate Administrator, Performing the Delegated Duties of the Assistant Secretary for Communications and Information, National Telecommunications and Information Administration, U.S. Dept. of Commerce, to Ajit Pai, Chairman, FCC, IB Docket No. 11-109, at 2 (filed Apr. 10, 2020) (NTIA Apr. 10, 2020 Letter). As part of its submission, NTIA enclosed two 2020 letters to the Department of Commerce from DOD, and a 2020 Air Force memorandum for NTIA's Interdepartmental Radio Advisory Committee (IRAC) Chairman from several federal agencies). In its letter, NTIA noted that the International Bureau's *2011 Order and Authorization* provides that the process for authorizing ATC operations would be complete "once the Commission, after consultation with NTIA, concludes that the harmful interference concerns have been resolved." *Id.*

<sup>65</sup> We note that on June 25, 2019, Ligado requested prompt Commission action in this proceeding under section 7 of the Communications Act. *See* Ligado Networks LLC's Request for Prompt Commission Action Under Section 7, IB Docket No. 11-109, IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, SAT-AMD-20180531-00044, SAT-AMD-20180531-00045, SES-AMD-20180531-00856 (citing 47 U.S.C. § 157(b)) (filed June 25, 2019) (Ligado Section 7 Request). Because of the actions we are taking in this order with respect to Ligado's license modification applications, Ligado's Section 7 Request is moot. We similarly disagree with a recent request from several parties, some of whom have actively participated in this proceeding, that we deny Ligado's applications and terminate this proceeding. *See* Letter from Aerospace Industries Association, *et al.* to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340 and 11-109, *et al.* (filed Apr. 15, 2020) (Coalition of Aviation, Satellite Communications, and Weather Information Users Apr. 15, 2020 *Ex Parte*). These commenters have had ample opportunity to comment on Ligado's 2018 proposal, and many of these commenters did so in 2018 and 2019 filings, and we have considered these comments as part of our decision.

### A. Public Interest Benefits

19. The network that Ligado proposes to deploy pursuant to its 2018 amendment differs significantly from the one conditionally approved in 2011.<sup>66</sup> Ligado now proposes to deploy a low-power terrestrial network in support of Industrial IoT (IIoT) services<sup>67</sup> using its MSS license in conjunction with ATC authority for terrestrial operations (through drastically reduced downlink power levels from those initially proposed). In addition to providing a standards-based satellite IIoT network and custom private network solutions in the industrial sector, Ligado intends to partner with carriers to support more broad-based 5G deployment.<sup>68</sup>

20. Establishing a path forward for Ligado to deploy its low-power terrestrial network in support of IIoT services and custom private network solutions will allow it to take advantage of its ATC authority and harness the benefits of combined MSS and ancillary terrestrial operations. As the Commission has stated, a licensee's ability to control both MSS and terrestrial operations in its L-Band spectrum can facilitate increased network capacity, more efficient use of spectrum, enhanced competition, and economies of scale in device manufacturing that can be passed on to consumers, all of which further the public interest.<sup>69</sup> The Commission recognized these benefits in 2003, when it adopted rules enabling an MSS operator to seek modification of its existing MSS license to obtain ATC operational authority.<sup>70</sup> While the International Bureau first granted Ligado's predecessor-in-interest ATC authority in 2004,<sup>71</sup> Ligado could not commence commercial service under that authority until it addressed the GPS industry's interference concerns, via the process set forth in 2011.<sup>72</sup> Having engaged with the GPS industry for several years to reach resolution of these concerns through private agreements, Ligado is now in a position to use its MSS and ATC authority to bring to the public the benefits of a terrestrial network supporting IoT services.

21. Further, Ligado's ability to use both satellite and terrestrial operations to deploy its planned network will advance our goals of bringing advanced communications services to the public and making more spectrum available for private and commercial use. Ligado currently plans to support an array of IIoT deployments and to deliver high-quality, secure IoT connections for small fixed and mobile

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<sup>66</sup> In approving the SkyTerra/Harbinger transfer of control application in 2010 and subsequent ATC waiver in 2011, the Commission anticipated the provision of a ubiquitous, integrated satellite/terrestrial 4G mobile broadband network to provide voice and data mobile wireless services nationwide, including to rural areas that lack service from then existing wireless providers. As conditioned in 2010, the network was to provide coverage to 260,000,000 people by December 2015. Since 2015, Ligado's business plans have changed materially to reflect the practical realities of operating under the technical parameters they now seek.

<sup>67</sup> See Letter from Gerard J. Waldron, Counsel to Ligado, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 (filed Aug. 6, 2019) (Ligado Aug. 6, 2019 *Ex Parte*); see also Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, WTB Docket No. 19-116, RM-11681 and Attach., "Ligado Networks: Facilitating a 5G Future with Mid-Band Spectrum" (filed May 3, 2019) (Ligado May 3, 2019 *Ex Parte*).

<sup>68</sup> Ligado Aug. 6, 2019 *Ex Parte* at 8.

<sup>69</sup> See, e.g., *Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems*, IB Docket No. 13-213, RM-11685, Report and Order, 31 FCC Rcd 13801, 13802-03, para. 4 (citing *ATC Report and Order*, 18 FCC Rcd at 1965, 1973-89 and 2064-65, paras. 2, 20-45, and 210-11).

<sup>70</sup> *ATC Report and Order*, 18 FCC Rcd at 2077, para. 240.

<sup>71</sup> See *2011 Order and Authorization*, 26 FCC Rcd at 568, para. 4 & n.13.

<sup>72</sup> *Id.* at 568, 586, paras. 4, 41-43.

devices.<sup>73</sup> Indeed, Ligado’s proposed service could develop as a key infrastructure component of the digital economy. The public interest is served by enabling Ligado to “accelerate digital transformations and modernize American infrastructure by building customer-focused networks that connect the next generation of IIoT.”<sup>74</sup> For example, Ligado plans to “deliver focused, highly secure and ultra-reliable communications over custom private networks to specific geographic locations” that serve the IIoT market for railroads, trucking, utilities, public safety, oil and gas, aviation, autonomous vehicles, and other critical infrastructure industries.<sup>75</sup>

22. Through its combined MSS and ATC authority, Ligado is uniquely positioned among potential IIoT providers to offer these types of service. For example, Ligado intends to provide service to the U.S. rail industry, with widely distributed operations covering over 138,000 track miles, requiring “ubiquitous network coverage, network control and customization, and highly reliable performance that 5G private networks seek to provide to industrial facilities.”<sup>76</sup> By leveraging its satellite operations in combination with terrestrial service, Ligado can provide access to IIoT services in rural areas and other communities that terrestrial networks alone cannot effectively reach. Ligado’s more comprehensive network, built upon both its MSS and ATC authority, will help solve these access problems, and foster innovative IIoT services in these communities, thereby helping to close the digital divide.

23. Additionally, Ligado’s deployment of its ancillary terrestrial network furthers our goal of efficiently using spectrum to support services that comprise the 5G ecosystem. Specifically, Ligado’s planned IIoT service offering is one of the 5G uses cases envisioned by the 3rd Generation Partnership Project (3GPP).<sup>77</sup> IIoT incorporates elements of two of the three “cornerstones” of 5G—massive machine type communication and ultra-reliable and low latency communications. 5G IIoT applications do not require the high data rates typically associated with enhanced mobile broadband, but offer many other beneficial features, such as extremely low latency, high reliability, and resiliency, which are critical to many industrial use cases. Standards development for IIoT as a 5G use case is well underway and there are ongoing 3GPP activities related to using 5G-New Radio (5G-NR) for IIoT solutions.<sup>78</sup> 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.<sup>79</sup> Nokia and Ericsson have conducted studies to formulate specific inputs for Ligado’s 3GPP plan to standardize and commercialize the Ligado spectrum band,<sup>80</sup> and each study found that Ligado’s spectrum, combined with

<sup>73</sup> Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, SAT-AMD-20180531-00044, and SAT-AMD-20180531-00045, at 1 (filed Aug. 14, 2018) (Ligado Aug. 14, 2018 *Ex Parte*).

<sup>74</sup> *Id.* at 1.

<sup>75</sup> See Ligado May 31, 2018 *Ex Parte* at 2; see also Ligado June 5, 2017 *Ex Parte*, Attach. at 1; Ligado Mar. 15, 2017 *Ex Parte* at 1.

<sup>76</sup> Ligado Aug. 6, 2019 *Ex Parte* at 6.

<sup>77</sup> 3GPP unites seven telecommunications standard development organizations, including the Alliance for Telecommunications Industry Solutions (the standards development organization that applies 3GPP standards in the United States). 3GPP, About 3GPP, <https://www.3gpp.org/about-3gpp> (last visited Apr. 10, 2019). 3GPP “covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities” “and thus provides complete system specifications.” *Id.*

<sup>78</sup> See Cisco, “Demystifying 5G in Industrial IoT” at 2, White Paper (2019), [https://www.cisco.com/c/dam/en\\_us/solutions/iot/demystifying-5g-industrial-iot.pdf](https://www.cisco.com/c/dam/en_us/solutions/iot/demystifying-5g-industrial-iot.pdf). Finalization of the 3GPP 5G standard supporting IIoT is expected by the end of 2019.

<sup>79</sup> Ligado Section 7 Request at 11; see also Ligado Aug. 6, 2019 *Ex Parte* at 6-7.

<sup>80</sup> Ligado Section 7 Request at 11.

higher-band spectrum, has the potential to improve the 5G user experience.<sup>81</sup> Additionally, Ligado has outlined a plan to complement industry deployments as a spectrum partner, building commercial partnerships that support customer private network solutions.<sup>82</sup> We find that our decision here will help facilitate these partnerships and Ligado's implementation of standards-based technology to provide connectivity to both satellite and terrestrial devices.

24. We also note that Ligado's network deployment has the potential to enhance network capability and create job growth. Specifically, Ligado plans to invest up to \$800 million in its satellite and terrestrial network capabilities, which it claims could create at least 8,000 jobs.<sup>83</sup>

**B. Ligado's Actions to Address GPS Harmful Interference Concerns Through Agreements with Major GPS Device Manufacturers**

25. Consistent with the International Bureau's directive set forth in the *2011 Order and Authorization*, Ligado has worked with the GPS industry to identify technical and operational measures to reduce the risk of overload interference to GPS devices and to take steps to enable its terrestrial operations to co-exist with GPS devices.<sup>84</sup> Through these agreements, Ligado has sought to address harmful interference concerns relating to GPS receivers.

26. Ligado has reached several co-existence agreements with major GPS device manufacturers. Specifically, as discussed below, Ligado has entered into agreements with six major GPS equipment manufacturers to address interference concerns that had been raised or identified with respect to potential harmful interference to GPS devices. These manufacturers agree that their GPS devices can co-exist with Ligado's proposed terrestrial operations (as described below), and Ligado in turn has committed to specific undertakings (including advance notification of its station deployments) and other steps designed to protect GPS receivers from harmful interference. As discussed below, these major GPS device manufacturers, when taken together, have been and continue to be involved in the development of many of the GPS devices and GPS-enabled products available for use—including general location and navigation, general non-certified aviation, and high-precision devices that are used in the United States and throughout the world. Each of these manufacturers also has participated in this proceeding, and many of their devices have been tested in the different studies and reports submitted in this proceeding since 2011.

27. *Respective agreements with major GPS device manufacturers Garmin, Deere, and Trimble.* We agree with Ligado that Garmin, Deere, and Trimble are important GPS device manufacturers in the GPS device ecosystem.<sup>85</sup> Garmin manufactures general location and navigation,

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<sup>81</sup> For example, Ericsson's study found that using Ligado's spectrum in conjunction with higher-band spectrum would deliver "user experience benefits and performance improvements for 5G as compared to a higher mid-band only deployments . . . [confirming that] multiple technology paths exist to utilize spectrum [to] provide the optimal solution for combined spectrum use for 5G." Ligado Section 7 Request at 12 (quoting Ericsson, *Study of L-Band Spectrum to Address C-Band Deployment Challenges* (June 2019)). Similarly, Nokia's study found that the "[c]ombined use of spectrum in the lower mid-band and higher mid-band categories offers significant economic and operational advantages for 5G as compared to higher mid-band only alternatives." *Id.* at 11-12 (quoting Nokia Corp., *Nokia's Study on Ligado Lower Mid-Band Spectrum Solution to Address 5G Deployment Challenges* at 4 (June 2019)).

<sup>82</sup> See Ligado Aug. 6, 2019 *Ex Parte* at 5.

<sup>83</sup> Ligado May 31, 2018 *Ex Parte* at 2.

<sup>84</sup> See *2011 Order and Authorization*, 26 FCC Rcd at 586, para. 42.

<sup>85</sup> See, e.g., Comments of Ligado Networks LLC at 14 (filed May 23, 2016) (Ligado May 23, 2016 Comments).

auto, and general non-certified and certified aviation devices.<sup>86</sup> Deere, in turn, manufactures high-precision GPS receivers and GPS-derived technology and incorporates them into its agricultural, construction, surveying, and other equipment, which is used by industry throughout the world.<sup>87</sup> Trimble provides GPS-enabled products, including general location and navigation and high-precision systems for commercial users throughout the world and for the U.S. Government.<sup>88</sup> Ligado has explained that these manufacturers represent the majority of the GPS device markets, as Garmin supplies the vast majority of the personal navigation device market, which makes up the largest subset of devices in the consumer-facing general location and navigation device market<sup>89</sup> and the vast majority of the certified aviation device market,<sup>90</sup> while Trimble and Deere together represent over half of the high-precision device market.<sup>91</sup> Prior to entering into these agreements, these three manufacturers (individually and together) had been major advocates in opposing Ligado's proposed terrestrial network. We note that these GPS device manufacturers incorporate into many of their GPS-enabled products the ability to operate also using other GNSS signals.<sup>92</sup>

28. Consistent with its 2015 license modification applications, Ligado committed with each of these manufacturers to permanently abandon terrestrial use of the 1545-1555 MHz portion of its MSS

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<sup>86</sup> Garmin May 23, 2016 Comments at 2; *see also* Ligado May 23, 2016 Comments, Attach., Coleman Bazelon, "Putting Mid-Band Spectrum to Work: Sharing between Ligado Networks and its GPS Neighbors," The Brattle Group, at Appx. 1, Tbl. 9 (May 23, 2016) ("Brattle Group Report"). Garmin has "evolved as the leading, worldwide provider of navigation, communications, and information devices and applications." Garmin May 23, 2016 Comments at 2. Garmin "designs, develops, manufactures, markets and distributes a diverse family of hand-held, wearable, portable and fixed-mount GPS-enabled products and other navigation, communications, sensor-based and information products." Garmin Ltd., Annual Report at 5 (Form 10-K) (Feb. 20, 2019).

<sup>87</sup> Deere Aug. 1, 2011 Comments at 5-6; Deere Jul. 7, 2016 Comments, Attach., Letter from Mark Lewellen, Manager of Spectrum Advocacy, John Deere, to Sheryl Genco, NASCTN Project Manager at 1 (June 13, 2016) (responding to NASCTN's draft test proposal and noting that Deere is "a prominent United States-based global manufacturer of state-of-the-art high precision GPS receivers and GPS-derived technology, including many advanced agricultural applications critical to feeding our planet and responsibly managing its resources."); *see also* Deere & Company, Annual Report (Form 10-K) (Dec. 17, 2018); Brattle Group Report, Appx. 1, Tbl. 9.

<sup>88</sup> Trimble Comments May 23, 2016 at 2-3 ("Trimble is a leading provider of advanced positioning solutions using [GPS], [GNSS], their augmentations, laser, optical, and inertial technologies. Trimble integrates such technologies with application software, wireless communications, and services to provide complete commercial solutions and to make field and mobile workers in businesses and government significantly more productive."); Brattle Group Report, Appx. 1, Tbl. 9.

<sup>89</sup> Ligado May 23, 2016 Comments at 14 (stating that as of 2015, Garmin supplied "84 percent of the personal navigation device ('PND') market, the largest subset of devices in the consumer-facing general location and navigation ('GLN') device market.") (citing Brattle Group Report, Appx. 1, Tbl. 9). According to the Brattle Group Report, as of 2015, Garmin represented 48 percent of the total GLN device market share. Brattle Group Report, Appx. 1, Tbl. 9.

<sup>90</sup> Brattle Group Report, Appx. 1, Tbl. 9 (stating that, as of 2015, Garmin held 71 percent of the certified aviation device market share).

<sup>91</sup> Ligado May 23, 2016 Comments at 14 (stating that, as of 2015, Trimble and Deere together represented 51 percent of the high-precision market); *see also* Brattle Group Report, Appx. 1 and Tbl. 9 (same).

<sup>92</sup> *See, e.g.*, Garmin Muya T9 Receiver for CORS (Satellite signals: GPS L1, GLONASS G1, DBS B1, Galileo E1), <https://www.garmin.com/US/en/product/muya-t9-gnss-receiver-cors/>; NAVCOM, A John Deere Company, <https://www.navcomtech.com/en/ourcompany/aboutnavcom/Deere> (discussing Deere GNSS products); Trimble July 9, 2018 Comments at 2 (stating that Trimble is a leading provider of advanced positioning solutions using GPS and GNSS). *Cf.* Garmin July 9, 2018 Comments at 13 (expressing concern that GPS and other GNSS technologies not be adversely affected); Deere July 9, 2018 Comments at 2 (Deere's primary interest is to ensure that Ligado's proposed network will not cause interference to the adjacent U.S. GPS and other international GNSS).



band nearest to the RNSS band.<sup>93</sup> In its agreement with Garmin, Ligado also included several ATC network restrictions, including: (1) limits on handset transmit power in the 1627.5-1637.5 MHz band; (2) OOB limits; (3) a defined frequency plan; (4) advance notice of activation of base stations; and (5) a review of production-quality sample handsets (at Garmin's request).<sup>94</sup> Garmin agreed that, apart from receiver overload or other interference to certified Garmin GNSS aviation equipment caused by Ligado's ATC use, Garmin would not object for a period of seven years to Ligado's use of the 1526-1536 MHz spectrum up to and including power levels at 32 dBW.<sup>95</sup>

29. Similarly, in Ligado's agreement with Deere, Ligado agreed to limit the power levels and OOB limits for both its handsets and base stations (including an EIRP power not to exceed 32 dBW for its base station downlink power in the 1526-1536 MHz band) and to provide advance notice of activation of base stations.<sup>96</sup> Deere, in turn, agreed not to object to Ligado's development of a network in the spectrum bands 1526-1536 MHz, 1627.5-1637.5 MHz, and 1646.5-1656.5 MHz so long as such deployment is consistent with the terms of the agreement.<sup>97</sup>

30. In its agreement with Trimble, Ligado committed to adhere to certain uplink power levels and OOB limits as well. Ligado agreed to maintain records of base station activations involving use of the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz bands and to provide Trimble with reasonable access to such records upon request—subject to Trimble maintaining the confidentiality of such information.<sup>98</sup> Both Ligado and Trimble agreed to support continued consideration of terrestrial use of the 1526-1536 MHz band in the then-pending DOT ABC Assessment study on a timetable and in accordance with the plans established by DOT.<sup>99</sup>

31. As support for its 2015 license modification applications, Ligado submitted a study by Coleman Bazelon of the Brattle Group, entitled "Putting Spectrum to Work: Sharing Between Ligado Networks and Its GPS Neighbors" (Brattle Group Report),<sup>100</sup> as well as an overview of the GPS device market and supporting declaration from Bill Alberth, former Chief Technology Officer at Motorola Mobility, who analyzed the GPS device categories and applications, including specific manufacturers associated with each identified GPS device category.<sup>101</sup> The GPS Industry Overview specifically

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<sup>93</sup> Garmin Agreement at 20; Deere Agreement at 1; Trimble Agreement at 2.

<sup>94</sup> Garmin Agreement at 17-18.

<sup>95</sup> Garmin Agreement at 22. The agreement did not address the merits of whether a 1 dB decrease in the  $C/N_0$  measure should be adopted by any agency, or legislative or lawmaking body. *Id.* at 19. Garmin also agreed that it would not object to Ligado's terrestrial deployment in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz frequency bands under the conditions Ligado now proposes in the modification applications. *Id.* at 23.

<sup>96</sup> Deere Agreement at 1-4.

<sup>97</sup> *Id.* at 2. The agreement expressly provided that its terms do not apply to either the participation of Ligado or Deere in the DOT ABC Assessment or any assessment of interference to GNSS receivers (including on the basis of a 1 dB decrease in the  $C/N_0$  measure) by any agency, or legislative or lawmaking body. *Id.* at 6-7.

<sup>98</sup> Trimble Agreement at 1-2.

<sup>99</sup> *Id.* at 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. *Id.*

<sup>100</sup> See Ligado May 23, 2016 Comments, Attach., Brattle Group Report. The Brattle Group Report provides an overview of the commercial GPS market, summarizes the GPS device categories and applications, estimates the current and projected market for GPS devices in the United States, and then overviews GPS receiver architecture and key components and relates them to the supply chain for GPS receivers. See generally Brattle Group Report.

<sup>101</sup> See Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, RM-11681; IB Docket Nos. 11-109 and 12-340, IBFS File Nos. SES-MOD-2011231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091 (filed Feb 11, 2016) (Ligado Feb. 11, 2016 *Ex Parte*) (attaching

(continued....)

identifies Garmin, Trimble, and Deere (as well as Topcon and Leica) as important manufacturers in four of the categories of devices that had been identified in the 2011 Working Group Report: general/location navigation (Garmin and Trimble), high-precision (Trimble, Deere, Topcon, and Leica), timing (Trimble), and certified aviation (Garmin).<sup>102</sup> Ligado contends that the Brattle Group Report and GPS Industry Overview show that reaching agreements with these companies about its proposed set of operating parameters would benefit the entire GPS industry by addressing interference concerns for all GPS device manufacturers.<sup>103</sup> According to the Brattle Group Report, for instance, Garmin supplies a large part of the general location/navigation market, Trimble and Deere supply a majority of the high-precision devices, and Trimble provides a large share of the timing products in the market.<sup>104</sup> Relying on the data compiled in the GPS Industry Overview, Alberth concludes that a relatively small number of suppliers and manufacturers can influence the GPS device supply chain.<sup>105</sup> Alberth explains that components of GPS consumer devices come from a limited number of suppliers, are sold “off-the-shelf,” and are not modified by manufacturers when they assemble their devices.<sup>106</sup> As a result, Alberth asserts that when a leading device manufacturer like Garmin makes design specifications, the component supplier will implement those changes to all component devices;<sup>107</sup> therefore, to the extent Garmin “negotiate[s] for operational limits on [Ligado] that result in [Ligado’s] handsets not causing harm to Garmin consumer devices, those same limits will benefit other GPS companies” because they “share a common supply chain and thus use similar or identical GPS device component parts.”<sup>108</sup> Ligado claims that this “ripple effect will ensure that, to the extent any modifications are necessary, other GPS consumer device manufacturers will necessarily incorporate any such modifications and therefore those devices will be similarly unaffected by adjacent band signals from the planned Ligado operations.”<sup>109</sup>

32. *Subsequent agreements with other major GPS/GNSS device manufacturers.*<sup>110</sup> In 2016, NovAtel and Topcon, after initially raising concerns about Ligado’s proposed terrestrial network, each filed joint letters with Ligado supporting Ligado’s modification applications.<sup>111</sup> NovAtel, which provides

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Declaration of Bill Alberth (Alberth Decl.) and a presentation entitled “GPS Device Market and Supply Chain Overview” (GPS Industry Overview)).

<sup>102</sup> See generally GPS Industry Overview at 2 (“Summary of GPS Device Categories and Applications”).

<sup>103</sup> See Ligado Feb. 11, 2016 *Ex Parte* (citing Alberth Decl. at 6); see also Letter from Gerard J. Waldron and Ani Gevorkian, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 and 12-340, IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SES-MOD-20121001-00872, at 1 (filed Jan. 13, 2016) (Ligado Jan. 13, 2016 *Ex Parte*). Ligado states that Garmin and Deere GPS devices “populate nearly all of the different categories of GPS devices”—specifically general location/navigation (several subcategories), high-precision, and timing. Ligado Jan. 13, 2016 *Ex Parte* at 1 and Attach. B. With regard to the cellular smartphone category, Ligado stated that no one had raised any interference issues. *Id.* at 1-2; see also Brattle Group Report at 21-22 (“by codifying power modifications for all GPS manufacturers and clearing the way for the development of augmented precision in GPS functionality, the Modification Applications benefit the GPS industry overall. That is, the Modification Applications, if adopted, guarantee interference-free reception of GPS signals going forward.”).

<sup>104</sup> Brattle Group Report, Appx. 1, Tbls. 5, 9.

<sup>105</sup> Alberth Decl. at 6.

<sup>106</sup> *Id.* at 3-4.

<sup>107</sup> *Id.* at 5.

<sup>108</sup> *Id.* at 5, 7; Ligado Feb. 11 *Ex Parte* at 2.

<sup>109</sup> Ligado Feb. 11, 2016 *Ex Parte* at 2; see also Brattle Group Report at 31.

<sup>110</sup> “GPS/GNSS” devices are devices that are enabled both by receiving GPS as well as other GNSS satellite signals.

<sup>111</sup> NovAtel Jun. 28, 2016 *Ex Parte*; Topcon Nov. 29, 2016 *Ex Parte*.

OEM GPS-enabled products (including GPS/GNSS products) and sells high-precision receivers to a number of system integrators that use the products in varied applications,<sup>112</sup> offered support based on a co-existence agreement with Ligado that “calls for future coordination prior to network deployment and for equipment refinements as needed.”<sup>113</sup> Likewise, Topcon, a provider of high-precision GPS-enabled devices (including GPS/GNSS devices), offered support after Topcon and Ligado performed testing and analysis to evaluate the potential impact of the proposed modifications, and the two companies “reached a cooperation agreement which calls for future coordination prior to network deployment and for mitigation efforts that may be needed.”<sup>114</sup> In 2016, Leica also indicated support for Ligado’s proposal based on NovAtel’s support.<sup>115</sup> And, in 2018, Hexagon, an equipment manufacturer of high-precision GPS/GNSS components and subsystems (including receivers, antennas, and firmware), indicated that it had reached agreement with Ligado to develop tools to mitigate the impact of intentional and unintentional interference within the GNSS band and make GPS-enabled devices more resilient not only against adjacent band operations but also against many other sources of possible interference.<sup>116</sup>

33. *Comments from another GPS/GNSS device manufacturer.* More recently, in October 2018, Septentrio, a worldwide designer and manufacturer of multi-frequency GPS/GNSS receivers and surveying equipment, filed a letter stating that it had worked with Ligado to refine some high-precision offerings and that Septentrio hardware and Ligado services were complementary.<sup>117</sup> Septentrio also noted that any interference from Ligado’s proposed operating parameters fell within the type of interference to which GNSS receivers can be immune by design.<sup>118</sup>

34. *Discussion.* We find that the co-existence agreements that Ligado has reached with each of the manufacturers discussed above are significant and support the Commission’s finding that technical and operational solutions to address concerns about harmful interference to GPS receivers have been developed<sup>119</sup> and that, with appropriate notifications and other conditions (discussed below), these

<sup>112</sup> See generally NovAtel May 19, 2016 Letter Comments at 2. See generally About NovAtel – Company Overview, <https://www.novatel.com/about-us/company-overview/>; (discussing GNSS devices); NovAtel High Precision GNSS & GPS Receivers, <https://www.novatel.com/support/info/view/gnss-receivers> (same).

<sup>113</sup> NovAtel Jun. 28, 2016 *Ex Parte* at 1.

<sup>114</sup> 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>.

<sup>115</sup> Leica Geosystems June 28, 2016 *Ex Parte*. See generally GNSS Systems / Leica Geosystems, <https://leica-geosystems.com/en-us/products/gnss-systems> (discussing Leica’s GNSS-enabled devices).

<sup>116</sup> Hexagon May 7, 2018 *Ex Parte* at 1.

<sup>117</sup> 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*). We note that Septentrio devices were included in tests conducted in the DOT ABC Report (see discussion below).

<sup>118</sup> *Id.* at 2.

<sup>119</sup> 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.” *Id.*

solutions can address other potential harmful interference concerns as Ligado's terrestrial network operations are rolled out over time. We believe that Ligado's efforts to work with and reach co-existence agreements with major GPS device manufacturers demonstrate the diligence with which Ligado has attempted to address adjacent band concerns, consistent with the directive set forth by the International Bureau in the *2011 Order and Authorization*. However, it is the Commission's responsibility to ensure that Ligado's revised proposal sufficiently protects against harmful interference to other services.

**C. Approach for Evaluating Potential Harmful Interference to GPS Devices Other Than Certified Aviation Devices**

35. In this section, we discuss the approach that the Commission will use when evaluating the potential harmful interference concerns relating to most GPS devices (i.e., all categories of GPS devices other than certified aviation receivers, which must meet specified equipment standards established by the FAA). As noted in the *2016 Comment PN* seeking comment on Ligado's 2015 license modification applications, the Commission defines "harmful interference" as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations."<sup>120</sup> Consistent with this definition, the Public Notice asked for relevant technical information about affected GPS receivers (e.g., receiver category, receiver bandwidth) and their *performance or functioning* (e.g., break lock, loss of tracking, specific effects on location and timing accuracy).<sup>121</sup> This technical information would help the Commission determine whether additional measures, beyond those set forth in the 2015 license modification applications, would be necessary to address potential harmful interference concerns regarding Ligado's then-proposed terrestrial mobile network.<sup>122</sup>

36. Since Ligado filed its 2015 license modification applications, three reports involving the testing of GPS devices other than certified aviation receivers have been submitted into the record. The testing methodologies used in these reports to evaluate the potential interference issues differ in fundamental respects. The testing methodologies in the RAA and NASCTN Reports focus on various elements concerning the performance of GPS devices in providing satellite-based positioning services when a terrestrial network in Ligado's MSS downlink and uplink bands operates under the parameters set forth in Ligado's 2015 license modification applications (including power levels for downlink operations of up to 32 dBW and uplink operations at up to -7 dBW). In evaluating certain GPS and GNSS devices, the third report—the DOT ABC Report—does not examine performance of these devices in providing positioning accuracy.<sup>123</sup> It instead seeks to develop an "interference tolerance mask" for categories of receivers based on measuring whether any of these devices experience a 1 dB carrier-to-noise density ratio ( $C/N_0$ )<sup>124</sup> degradation in the reception of any GPS (or GNSS) satellite signal, which it contends will serve to ensure that the devices are not adversely affected by interference from Ligado's operations.<sup>125</sup>

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<sup>120</sup> *2016 Comment PN*, 31 FCC Rcd at 3809 n.48 (citing 47 CFR § 2.1(c) (definition of "harmful interference")). We note that "harmful interference" is different and distinct from "interference." See *id.* (defining "interference" as "[t]he effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.").

<sup>121</sup> *Id.* at 3809.

<sup>122</sup> *Id.*

<sup>123</sup> Accordingly, we note that the DOT ABC Report does not directly address the "performance or functioning" of GPS devices, as had been requested in the *Comment PN*.

<sup>124</sup>  $C/N_0$  represents the ratio of the carrier signal power,  $C$ , to the existing environmental noise density power,  $N_0$ .

<sup>125</sup> DOT ABC Report at 18.

We discuss the differing testing methodologies immediately below.<sup>126</sup> We then conclude, for the reasons described below, 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.<sup>127</sup>

37. *RAA Reports.* 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).<sup>128</sup> In addition, the RAA testing included analyses that, Ligado contends, show that there is no evidence that a change of 1 dB in C/N<sub>0</sub>, a metric used by DOT and others, correlates to any significant error in a GPS device’s reporting of position or timing data,<sup>129</sup> and thus is not indicative of the presence of harmful interference.

38. *NASCTN Report.* 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.<sup>130</sup> In 2017, NASCTN issued its report, which Ligado had earlier commissioned.<sup>131</sup> 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. It then presented the resulting test method and data, which could be used to “establish the integrity of this and other test methods and ensure the quality of the collected data,

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<sup>126</sup> We discuss the substantive findings and conclusions of the various reports in the next section. *See infra* section III.D.

<sup>127</sup> As discussed below, where there are receiver standards that have been developed, as is the case with certified aviation receivers, we rely on those standards when evaluating harmful interference.

<sup>128</sup> June 2016 RAA Report at Table 2. For general location/navigation devices, it tested 12 devices (including 7 Garmin devices and 1 Trimble device); for high-precision it tested 11 devices (including 6 Trimble, 3 Topcon, and 1 NovAtel); and for general non-certified aviation it tested 1 device (Garmin). We note that many of the manufacturers represented were expressly identified in the Brattle Group Report as major GPS device manufacturers.

<sup>129</sup> *Id.* at 17 (the “average C/N<sub>0</sub> values reported by the receiver (averaged for all GPS satellites) showed random variations in excess of 1 dB in the absence of any adjacent band signals, and such variations did not accurately predict a device’s position accuracy”); *see also* Ligado June 5, 2017 *Ex Parte*, Attach. at 22-24 (“The test data collected by both RAA and NASCTN show[] that for most devices, C/N<sub>0</sub> can fluctuate by upwards of 5 dB without any impact of the device’s timing or position accuracy.”) (emphasis in original).

<sup>130</sup> *See* National Advanced Spectrum and Communications Test Network | NIST, <https://www.nist.gov/communications-technology-laboratory/nasctn> (last visited Aug. 12, 2019). NASCTN was created in 2015 and is a joint effort among the National Institute of Standards and Technology (NIST), the National Telecommunications and Information Administration (NTIA), the United States Department of Defense, the National Aeronautical and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration. *Id.* According to NASCTN’s charter, the organization’s purpose is to “improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.” Charter of the National Advanced Spectrum and Communications Test Network § 1, [https://www.nist.gov/sites/default/files/documents/2019/03/27/nasctn\\_charter\\_03.04.19.pdf](https://www.nist.gov/sites/default/files/documents/2019/03/27/nasctn_charter_03.04.19.pdf) (last visited Aug. 12, 2019).

<sup>131</sup> *See* Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, RM-11681 (filed Feb. 21, 2017) (discussing results of NASCTN Report); Letter from Gerard J. Waldron, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, RM-11681 (filed Feb. 24, 2017) (same).

including detailed uncertainty analysis of both the test conditions and the device under test (DUT) response.”<sup>132</sup> As part of NASCTN’s effort to support “a broad understanding of GPS receiver performance,” the test plan focused on a variety of measurands,<sup>133</sup> including carrier-to-noise density ratio (C/N<sub>0</sub>), 3D position error, timing error, number of satellites in view, time-to-first-fix (TTFF), and time-to-first-reacquisition (TTFR).<sup>134</sup> The report assessed each of these measurands across a large range of adjacent-band LTE power levels.<sup>135</sup> The underlying goal was rigorous testing of each device under test (DUT) configured for typical use; the resulting details and descriptions were meant to facilitate similarly rigorous testing of additional devices.<sup>136</sup> The NASCTN Report tested 14 devices in different categories, including general location/navigation receivers, high-precision (including real-time kinematic) receivers, and GPS-disciplined oscillator (i.e., timing) receivers.<sup>137</sup> NASCTN also tested several different antennas.<sup>138</sup> As NASCTN stated, the purpose of the report was to develop a rigorous (repeatable, calibrated, and well-documented) test method and to collect data to analyze impacts of proposed adjacent band LTE signals on GPS devices.<sup>139</sup> The NASCTN Report did not compare the test results with the results from other entities’ testing.<sup>140</sup>

39. *The DOT ABC Report.* In the 2018 DOT ABC Report, DOT assessed the maximum transmitted power levels of adjacent band radiofrequency systems that could be tolerated by categories of certain GPS and GNSS receivers by developing an “interference tolerance mask” (ITM) for each category of receiver that processed signals in the RNSS allocation.<sup>141</sup> Its methodology and analysis, in turn, were based on measuring where a device experienced a 1 dB C/N<sub>0</sub> degradation with respect to any satellite within view of the receiver, which DOT then used to establish an “interference protection criterion (IPC).”<sup>142</sup> The test did not examine whether the actual performance of the receivers was affected (e.g., in providing position accuracy), but instead concluded that, to ensure that a receiver’s operation is protected,

<sup>132</sup> NASCTN Report at 1. Prior to developing its final test plan and conducting its validation testing, NASCTN had solicited comment; it received input from spectrum regulators, federal agencies, GPS device manufacturers, and members of the public. *Id.* at vii.

<sup>133</sup> The NASCTN Report provides that, in this context, “measurands were data that are (1) observable to users (or third-party testers) from digital outputs of the [device under test, or DUT], (2) made available from the GPS simulator as the reference ‘truth,’ and/or (3) measurable at electrical outputs of the DUT.” *Id.* at 14.

<sup>134</sup> *Id.* at viii; *see generally id.*

<sup>135</sup> *Id.* at vii-viii; *see generally id.*

<sup>136</sup> *Id.* at 1 (Objective).

<sup>137</sup> *Id.* at 9-13 (these included Garmin, Leica, NovAtel, and Trimble devices). One of the 14 devices (Garmin Montana 680t) involved testing with two different types of firmware (2.20 and 2.54).

<sup>138</sup> *Id.* at 13 (these included antennas made by Arbiter, MicroSemi, Javad, Leica, NovAtel, and Trimble).

<sup>139</sup> *Id.* at 2 (Scope).

<sup>140</sup> NASCTN Report at ix-x (Executive Summary).

<sup>141</sup> DOT ABC Report at 118-19, 149, 152-53, 155. Prior to issuing its report, DOT solicited and received comment on its testing plans. *See* Dep’t. of Transp., Draft Test Plan to Obtain Interference Tolerance Masks for GNSS Receivers in the L1 Radiofrequency Band (1559-1610 MHz), 80 Fed. Reg. 54,368 (Sept. 9, 2015). For its report, DOT tested 80 civil GPS/GNSS devices at the White Sands Missile Range (WSMR) facility in April 2016, the week following the Air Force’s testing of military receivers at that facility. DOT ABC Report, Executive Summary at III. Ligado has consistently opposed the 1 dB metric and testing methodology employed in the report, contending that this approach did not address harmful interference concerns.

<sup>142</sup> *See* DOT ABC Report at 44-45; DOT ABC Assessment Test Plan (March 2016) at 1-4, <https://rosap.ntl.bts.gov/view/dot/37033>.

it must not experience such a 1 dB C/N<sub>0</sub> degradation in reception of a satellite signal.<sup>143</sup> For this report, DOT examined a total of 80 civil GPS and GNSS devices in six categories in 2016—including cellular, general location/navigation, high-precision, timing, general aviation (non-certified), and space-based receivers.<sup>144</sup> The report summarized in two tables its findings on what it deemed to be maximum tolerable power levels for base stations necessary to protect each category of receivers.<sup>145</sup> With the goal of providing tolerable levels for *all* tested receivers,<sup>146</sup> the proposed protection level in each category was based upon the one receiver *most* susceptible to experiencing a 1 dB degradation in the reception of a satellite signal. As with previous testing in this proceeding, in DOT's testing under its methodology, the cellular category was least potentially affected by transmissions in the lower portion of the MSS band, while the high-precision category was the most affected.<sup>147</sup>

40. Apart from these three studies that tested GPS devices, the 2018 NPEF Gap Analysis was submitted into the record.<sup>148</sup> This report did not test any devices; instead, it performed a general assessment of the testing methodologies used to analyze the impacts of adjacent band interference on GPS receivers, and it sought to identify certain unanswered questions or untested conditions.<sup>149</sup> The NPEF Gap Analysis determined that, of the testing reports it evaluated (the RAA Reports, the NASCTN Report, the DOT ABC Report, the 2011 TWG Final Report, and two other NPEF reports from 2011), only the DOT ABC Report and the three 2011 reports met all of NPEF's requisite criteria—which included “strict application” of the 1 dB metric criterion for the “worst case” conditions.<sup>150</sup> The NPEF Gap Analysis then concluded that only the data from those latter reports should be considered in order to ensure that existing and evolving uses of GPS devices are not affected.<sup>151</sup>

41. *Positions of Ligado and the commenters.* Ligado asserts that the RAA and NASCTN Reports, which rely upon receiver performance for evaluating potential interference, provide reliable and relevant technical bases for such evaluation, consistent with the Commission's “harmful interference” definition.<sup>152</sup> According to Ligado, these reports, taken in conjunction with Ligado's agreements with major GPS device manufacturers (including its commitments to them), demonstrate that Ligado's operations can proceed without adversely affecting the operations of GPS receivers.<sup>153</sup> The Competitive Carriers Association supported the RAA testing on the ground that it was designed to test actual harm to

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<sup>143</sup> DOT ABC Report at 18; *see also id.* at 45. Notably, the test methodology did not limit its measurements to only those satellites used in the navigation solution.

<sup>144</sup> DOT ABC Report at 22-25. Nearly half of the tested devices (36 out of 80) were supplied by GPS device manufacturers that have entered into co-existence agreements with Ligado: 20 Trimble devices, 8 Garmin, 4 Septentrio devices, 3 Leica devices, and 1 Topcon device. *Id.*

<sup>145</sup> *Id.* at 103-05.

<sup>146</sup> *Id.* at 103.

<sup>147</sup> Under DOT's testing methodology and analysis, only the cellular receivers as a category have interference tolerance masks sufficient to ensure that their operations would not be harmed by Ligado's proposed transmissions at power levels of 9.8 dBW. The cellular devices do not, however, have masks sufficient to ensure that their operations would not be harmed by Ligado's earlier proposed operations at up to 32 dBW. *See id.* at 104-05.

<sup>148</sup> *See* NPEF Gap Analysis.

<sup>149</sup> *Id.* at 3.

<sup>150</sup> *Id.* at 9, 16.

<sup>151</sup> *Id.* at 16-17.

<sup>152</sup> Ligado July 9, 2018 Comments at 10-14.

<sup>153</sup> *Id.*

consumer devices, which it stated requires opponents to show harmful interference only by bringing forth specific, data-driven concerns.<sup>154</sup>

42. Ligado contends that the DOT ABC Report and any other testing or analysis (including the NPEF Gap Analysis) that is based on the 1 dB C/N<sub>0</sub> degradation metric is inconsistent with the Commission's approach to evaluating harmful interference, is technically flawed, and thus should not be considered by the Commission.<sup>155</sup> In particular, Ligado states that the DOT ABC Report does not speak directly to the interference issues before the Commission because it does not assess the potential for "harmful interference" (as defined by the Commission) to GPS devices or attempt to evaluate the receivers' actual performance when examining interference issues.<sup>156</sup> Ligado also contends that opponents who assert that the Commission has used the 1 dB metric in the manner they advocate are simply mistaken and that the Commission has never used that metric for evaluating harmful interference to operations in one band from transmissions in adjacent bands (i.e., for evaluating overload interference issues).<sup>157</sup> Ligado continues to challenge DOT's tests (as well as other earlier testing in this proceeding) given its reliance on a 1 dB metric methodology that Ligado contends has no reliable relationship to the actual performance of GPS devices.<sup>158</sup> It also claims that adopting a 1 dB metric as proposed would block use of spectrum adjacent to the RNSS allocation on either side by more than 60 megahertz.<sup>159</sup> Ligado also contends that the data gathered in the RAA testing and in the NASCTN Report confirms that a 1 dB decrease in the C/N<sub>0</sub> is not the appropriate standard for assessing harm to GPS receivers.<sup>160</sup>

43. Opponents of Ligado's proposed terrestrial network, in turn, generally rely on the DOT ABC Report and its assessment based on examining a 1 dB C/N<sub>0</sub> degradation metric with respect to GPS and GNSS devices. ASRI contends that the 1 dB metric should be used to assess potential interference to these GPS receivers.<sup>161</sup> ASRI notes that the DOT ABC Report states a power level of 9.8 dBW may cause interference with, or degradation to, most other categories of GPS/GNSS receivers, including those

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<sup>154</sup> Competitive Carriers Association May 23, 2016 Comments at 4; *see also* Technology Policy Institute May 19, 2016 Comments at 3 ("In addition, Ligado has submitted test results from Roberson and Associates showing that the GPS devices will work appropriately if the spectrum is used consistent with the conditions negotiated with the manufacturers. The agreements supplemented by the data from the test results should assure the Commission that the proposed license modifications will address the interference concerns raised by the GPS as well as the aviation sector's use of GPS.").

<sup>155</sup> *See, e.g.*, Ligado July 9, 2018 Comments at 11-14; Ligado April 12, 2018 *Ex Parte* at 2-3 (rejecting 1 dB criterion in NPEF Gap Analysis); Letter from Gerard J. Waldron and Hannah Lepow, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, *et al.* (filed Nov. 25, 2019) (Ligado Nov. 25, 2019 *Ex Parte*). ; Letter from Gerard J. Waldron and Ani Gevorkian, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, *et al.* (filed Jan. 13, 2020) (Ligado Jan. 13, 2020 *Ex Parte*).

<sup>156</sup> Ligado July 9, 2018 Comments at 11-12.

<sup>157</sup> Ligado July 19, 2018 Reply at 15-16; *Ex Parte* Letter from Valerie Green, Executive Vice President and Chief Legal Officer, Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, *et al.* at 8-10 (filed Nov. 21, 2019) (Ligado Nov. 21, 2019 *Ex Parte*).

<sup>158</sup> Ligado July 9, 2018 Comments at 11-14.

<sup>159</sup> *Id.* at 12; *see also* Ligado Nov. 25, 2019 *Ex Parte* at 2 ("The ABC Report clearly shows that the 1 dB metric would impose an unworkable power limit on *100 megahertz of vital spectrum beyond the spectrum allocated to Ligado.*") (emphasis in original).

<sup>160</sup> June 2016 RAA Report at 17; Ligado Feb. 24, 2017 *Ex Parte* at 2 & Attach. (citing NASCTN Report and attaching pages 125-128, 191, and 274-75 of the report).

<sup>161</sup> ASRI July 24, 2018 Reply at 2.



used for general aviation and drones.<sup>162</sup> GPS/SATCOM Coalition, which also opposes Ligado's proposal, points to the March 2018 NPEF Gap Analysis, which supports DOT and other testing that relied on the 1 dB metric and concluded that Ligado's transmissions would result in unacceptable interference to GPS receiver operations.<sup>163</sup> We note that throughout this proceeding other commenters also have expressed their general support for use of the 1 dB metric in this proceeding.<sup>164</sup> In addition, although Garmin, Trimble, and Deere have reached their own co-existence agreements with Ligado, they continue to support the use of the 1 dB metric to assess harmful interference, and they object to Ligado's proposal to use an alternative metric to assess potential harmful interference.<sup>165</sup> Trimble states that the GNSS industry, the FCC, and NTIA have used the 1 dB metric in various contexts for many years.<sup>166</sup> Garmin contends that the 1 dB metric should be applied to protect GPS devices not only from OOB that emanate from services in adjacent bands (here, Ligado's transmissions in the MSS band) and fall within the RNSS band where GPS operates, but also to overload interference that emanates from services in adjacent bands (here Ligado) and falls outside the RNSS band.<sup>167</sup>

44. Some commenters also raised concerns specific to the RAA Report or the NASCTN Report. Garmin and Trimble criticized the RAA testing's methodology, noting, for example, that it yielded only a partial dataset for a limited number of KPIs or performance indicators,<sup>168</sup> while u-blox expressed concern that the RAA testing did not test the full range of OEM devices that would be impacted.<sup>169</sup> The GPS Innovation Alliance expressed concerns about the limited nature of the NASCTN tests, questioned whether the 14 devices tested were representative of the GPS/GNSS receiver market, and noted that the report did not compare its test results with prior testing in this proceeding.<sup>170</sup> The GPS

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<sup>162</sup> ASRI July 24, 2018 Reply at 10 (citing DOT ABC Report at 158); *see also* Letter from Dana. A. Goward, President, Resilient Navigation and Timing Foundation, to the Hon. Ajit Pai, Michael O'Rielly, Brendan Carr, Jessica Rosenworcel, Geoffrey Starks, IB Docket Nos. 11-109 and 12-340 at 2 & Attach. at 9 (filed Nov. 14, 2019) (Resilient Navigation and Timing Foundation Nov. 14, 2019 *Ex Parte*) (expressing support for technical assessment in the ABC Report).

<sup>163</sup> Letter from Coalition of Aviation, SATCOM, and Weather Information Users, to Hon. Ajit Pai, Chairman, FCC, at 3-4 (filed July 18, 2018) (GPS/SATCOM Coalition June 18, 2018 *Ex Parte*).

<sup>164</sup> *See, e.g.*, Letter from F. Michael Swiek, Executive Director, GPS Innovation Alliance, to Marlene H. Dortch, Secretary, FCC, at 2-8 (filed July 13, 2017) (GPS Innovation Alliance July 13, 2017 *Ex Parte*); Letter from J. David Grossman, Executive Director, GPS Innovation Alliance, to Marlene H. Dortch, Secretary, FCC (filed Dec. 20, 2019) (GPS Innovation Alliance Dec. 20, 2019 *Ex Parte*).

<sup>165</sup> Garmin July 9, 2018 Comments at 9-13, Trimble July 9, 2018 Comments at 1, 4-10, Deere July 9, 2018 Comments at 3-4.

<sup>166</sup> Trimble May 23, 2016 Comments at 9.

<sup>167</sup> *See* Garmin May 16, 2018 *Ex Parte* at 2-3 (citing U.S. Air Force, SMC/GP (GPS Directorate), "Background Paper on Use of 1-dB Decrease in C/N<sub>0</sub> as GPS Interference Protection Criterion," June 2017, at 2, 6-9, [www.gps.gov/spectrum/ABC/1dB-background-paper.pdf](http://www.gps.gov/spectrum/ABC/1dB-background-paper.pdf)); *see also* Letter from J. David Grossman, Executive Director, GPS Innovation Alliance, to Marlene H. Dortch, Secretary, FCC, at 6 (filed Feb. 18, 2020) (GPS Innovation Alliance Feb. 18, 2020 *Ex Parte*).

<sup>168</sup> *See* Garmin May 23, 2016 Comments at 17 n.39; Trimble July 9, 2018 Comments at 3 (noting concern with use of KPIs to determine whether harmful interference has occurred); *see also* GPS Innovation Alliance Dec. 20, 2019 *Ex Parte* at 5 (noting concern that KPIs only reveal deficiencies at the time of operation, meaning that harmful interference may have already occurred).

<sup>169</sup> *See* Letter from Nikolaos Papadopoulos, President, u-blox America, Inc. to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109, at 1 (filed May 20, 2016).

<sup>170</sup> *See* GPS Innovation Alliance July 13, 2017 *Ex Parte* at 8-9; *see also* GPS Innovation Alliance Dec. 20, 2019 *Ex Parte* at 6 (noting concern that focus on KPIs, and position error in particular, ignores other GPS receiver operations

(continued....)

Innovation Alliance, Garmin, and Trimble also asserted that the NASCTN Report indirectly supports use of the 1 dB metric because the report reveals the difficulty and complexity of addressing all uses and all variations of devices (as compared, they contend, to a 1 dB metric approach), and directly supports a finding that there is some correlation between  $C/N_0$  degradation and receiver performance.<sup>171</sup>

45. In December 2019, NTIA submitted a letter to the Commission concerning Ligado's license modification applications.<sup>172</sup> NTIA states that based on assessments of the potential impacts of Ligado's proposals in the record, federal agencies have "significant concerns" regarding the impacts to their missions, national security, and the U.S. economy.<sup>173</sup> NTIA concludes that, despite the considerable efforts to find a satisfactory solution, it, on behalf of the executive branch, is "unable to recommend" the Commission's approval of the Ligado applications.<sup>174</sup> As part of its submission, NTIA enclosed three letters—a December 2018 letter to NTIA from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM) recommending that any current or future proposals to operate commercial services in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the "tolerable power transmission limits" described in the DOT ABC Report,<sup>175</sup> and two letters submitted by DOD to the Commission in June 2019 and November 2019 in which DOD points to the recommendation of the 2018 PNT EXCOM and the transmission limits set forth in the DOT ABC Report and states DOD's belief that there are too many "unknowns" and risks to federal operations, including a potential significant negative impact on military operations, to allow Ligado's proposed system to proceed.<sup>176</sup> According to DOD, the data show the potential for widespread disruption and degradation of GPS services from the proposed Ligado system.<sup>177</sup> Ligado responded to these filings, stating that NTIA's letter only vaguely states that some federal agencies have "significant concerns," and conveys no new information, data, or arguments, and makes no recommendation to the Commission,<sup>178</sup> while the DOD letters contain no data, analysis, or basis for their conclusions other than the DOT ABC

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such as time, velocity, or acceleration). Garmin also complained that data were collected on only four KPIs (and that the results of these were not available for all devices). See Garmin May 16, 2018 *Ex Parte* at 4-5.

<sup>171</sup> GPS Innovation Alliance July 13, 2017 *Ex Parte* at 9-11 (asserting, for example, that because the NASCTN Report shows a performance degradation in time to first fix within approximately 3 dB of the 1 dB  $C/N_0$  degradation point, there is a clear connection between signal reception (measured by  $C/N_0$ ) and the user experience, and that every dB of  $C/N_0$  is valuable); GPS Innovation Alliance Dec. 20, 2019 *Ex Parte* at 5; see also Garmin May 16, 2018 *Ex Parte* at 5-6 (citing GPS Innovation Alliance July 13, 2017 *Ex Parte*).

<sup>172</sup> NTIA Dec. 6, 2019 Letter.

<sup>173</sup> *Id.* at 2 (citing the 2018 DOT ABC Study, the NASCTN Report, the 2011 TWG Report, the 2011 and 2012 NPEF reports, and the 2016 RAA Report).

<sup>174</sup> *Id.*

<sup>175</sup> *Id.*, Enclosure 1 (letter from Dana Deasy and Heidi R. King, Acting Co-Chairs, EXCOM, to David J. Redl, Assistant Sec'y for Communications & Information, NTIA, (Dec. 3, 2018)).

<sup>176</sup> *Id.*, Enclosure 2 (Letter from Mark T. Esper, Sec'y, Department of Defense, to Ajit Pai, Chairman, FCC (Nov. 18, 2019) (DOD Nov. 18, 2019 Letter) (stating that, pursuant to 10 U.S.C. § 2281, the Secretary of Defense may not agree to any restriction on GPS that would adversely affect the military potential of GPS); Enclosure 3 (Letter from Patrick M. Shanahan, Acting Sec'y, Department of Defense, to Ajit Pai, Chairman, FCC (June 7, 2019) (DOD June 7, 2019 Letter) at 1 (same). Beyond reference to the DOT ABC Report, these letters do not provide any mention or discussion of any technical analyses in the record in this proceeding. See also NTIA Apr. 10, 2020 Letter (discussing potential impact on military operations).

<sup>177</sup> DOD Nov. 18, 2019 Letter at 1.

<sup>178</sup> Ligado Dec. 9, 2019 *Ex Parte* at 1-2.

Report, which relies on a 1 dB metric that is already being considered by the Commission.<sup>179</sup> Ligado contends that the record is complete, and includes extensive tests and facts that recommend that Ligado's applications, with extensive conditions to protect the stakeholders, be approved by the Commission.<sup>180</sup>

46. On April 10, 2020, NTIA submitted another letter to the Commission in which NTIA encloses a February 2020 Air Force memorandum and two March 2020 DOD letters and states that it believes that the Commission "cannot reasonably reach" a conclusion that harmful interference concerns have been resolved.<sup>181</sup> The Air Force memorandum, submitted to NTIA's Interdepartmental Radio Advisory Committee (IRAC), references earlier NPEF studies, a classified test of GPS receivers conducted by the Air Force in 2016 (which supported the conclusions drawn from DOT testing conducted in 2016 that formed the basis for the 2018 DOT ABC Report),<sup>182</sup> and the Dec. 6, 2019 NTIA letter (and enclosures), but does not include any new technical data on interference (instead focusing on Ligado's mitigation proposal).<sup>183</sup> The two DOD letters are addressed to the Department of Commerce, request that NTIA transmit the Air Force memorandum to the Commission for its consideration, and also do not provide any new technical data.<sup>184</sup> In response, Ligado asserts that these filings raise no new evidence, arguments, or claims.<sup>185</sup> With regard to the Air Force memorandum, Ligado states that the claims of threats to military use are unsupported, inappropriately rely on a 1 dB metric for its interference analysis, and ignore Ligado's amended 2018 license modification application in which Ligado reduced its proposed operating power levels from 32 dBW to 9.8 dBW, which will drastically reduce the impact of its proposed operations on GPS high-precision devices. It also states that Ligado has entered into co-existence agreements with major GPS device manufacturers who no longer object to Ligado's proposed operations.<sup>186</sup>

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<sup>179</sup> Ligado Nov. 21, 2019 *Ex Parte* (addressing the issues raised by both the July 2019 and November 2019 DOD letters); Ligado Jan. 21, 2020 *Ex Parte* at 1 (explaining that DOD's November 2019 letter contained no data, no analysis, and no basis for its conclusion other than the DOT ABC Report, which has been before the Commission since April 2018).

<sup>180</sup> Ligado Dec. 9, 2019 *Ex Parte* at 3.

<sup>181</sup> Letter from Douglas W. Kinkoph, Associate Administrator, Performing the Delegated Duties of the Assistant Secretary for Communications and Information, National Telecommunications and Information Administration, U.S. Dept. of Commerce, to Ajit Pai, Chairman, FCC, IB Docket No. 11-109, at 2 (filed Apr. 10, 2020) (NTIA Apr. 10, 2020 Letter). The enclosed Air Force memorandum was endorsed by representatives of the Department of the Army, Department of the Navy, Department of Commerce, NASA, Department of Interior, Department of Justice, Department of Homeland Security, Department of Energy, the National Science Foundation, DOT, the U.S. Coast Guard, and the FAA. See Memorandum for IRAC Chairman, NTIA, by Ms. Thu Luu, Department of the Air Force, Executive Agent for GPS at 6 (Feb. 14, 2020) (Air Force Feb. 2020 Memorandum).

<sup>182</sup> *Id.* at 1 n.1 (noting that the Air Force conducted GPS receiver testing at White Sands Missile Range (WSMR) in April 2016 "supported the conclusions drawn from the DOT testing at WSMR conducted that same month"). The Air Force conducted its testing of military receivers at the White Sands Missile Range (WSMR) facility before the DOT testing. DOT ABC Report, Executive Summary at III. The Air Force notes that the 2016 Air Force testing is classified, and it did not include this testing in the Commission's record.

<sup>183</sup> See Air Force Feb. 2020 Memorandum.

<sup>184</sup> Letter from David L. Norquist, Deputy Secretary, Department of Defense, to Hon. Wilbur L. Ross, Jr., Secretary, Department of Commerce (Mar. 24, 2020) (DOD Mar. 24, 2020 Letter) (citing 10 U.S.C. § 2281); Letter from Dana Deasy, Chief Information Officer, Department of Defense, and Michael Griffin, Under Secretary for Research and Engineering, Department of Defense, to Douglas W. Kinkoph, Deputy Assistant Secretary (Acting), NTIA (Mar. 12, 2020) (DOD Mar. 12, 2020 Letter) (citing 10 U.S.C. § 2281).

<sup>185</sup> Ligado Apr. 12, 2020 *Ex Parte* at 1.

<sup>186</sup> *Id.* at 2-3.

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  $C/N_0$  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.

48. We have before us technical studies that employ two different approaches. One approach uses performance-based metrics associated with GPS receiver operations, such as the error introduced to the accuracy of either the two-dimensional (2D) or three-dimensional (3D) position solution, depending on the specific GPS application under consideration, to examine whether Ligado's proposed system would cause harmful interference to GPS devices. The other approach for assessing potential interference to GPS receivers is the application of an interference protection criterion (IPC) represented by examining the GPS receivers to determine whether a 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, and accordingly does not directly address whether there would be any "harmful interference" as defined by the Commission. As discussed below, we also conclude that there are technical and policy reasons for not relying on the 1 dB  $C/N_0$  degradation metric approach applied in the DOT ABC Report and advocated by others, including NPEF in its Gap Analysis.<sup>187</sup>

49. In determining whether a new service would cause harmful interference to an incumbent service, we begin with and rely on the Commission's long-standing definition embodied in our rules: "harmful interference" is "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations."<sup>188</sup> We note NTIA defines "harmful interference" in the same manner,<sup>189</sup> as does the ITU.<sup>190</sup> We apply this definition for evaluating potential for interference with respect to all services and allocations, including those associated with RNSS in the 1559-1610 MHz band where GPS operates. Radio noise occurs throughout the spectrum and a small rise in background noise, however undesirable, does not by itself constitute harm to a service.

50. Contrary to the position of those commenters supporting use of the 1 dB  $C/N_0$  degradation metric, the Commission has not applied this metric as the determinant of harmful interference caused by emissions falling within the RNSS allocation nor has the Commission used this or any other metric to offer interference protection for GPS receivers that are particularly susceptible to interference substantially outside the RNSS allocation. In the MSS ATC proceeding, which was coordinated with

<sup>187</sup> We recognize that the NPEF Gap Analysis deemed the scope and framework of the NASCTN measurement campaign to be "insufficient" based on the "minimum criteria" supported by the Positioning, Navigation and Timing Advisory Board (PNTAB). NPEF Gap Analysis at 16. However, the basis for this categorization was the fact that NACSTN did not declare the 1 dB  $C/N_0$  reduction to be the sole interference criterion, even though it did indeed collect and report those data, in which case, the effort actually exceeds the specified PNTAB criteria associated with the NPEF studies. *Id.*

<sup>188</sup> 47 CFR § 2.1(c).

<sup>189</sup> NTIA's Manual of Regulations and Procedures for Federal Radio Frequency Management (2017), § 6.1.1, at 6-6, [https://www.ntia.doc.gov/files/ntia/publications/redbook/2017-09/6\\_17\\_9.pdf](https://www.ntia.doc.gov/files/ntia/publications/redbook/2017-09/6_17_9.pdf) (defining "harmful interference" to mean "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these Regulations").

<sup>190</sup> ITU Radio Regulations § 1.169 (defining harmful interference as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations (CS).").

NTIA (and with other federal agencies by NTIA), the Commission directly addressed the potential interference from ATC operations to GPS operations in the adjacent 1559-1610 MHz RNSS allocation. In allowing for ATC operations in the Commission's ATC rulemaking in 2003, the Commission adopted a wideband OOB limit of -70 dBW/MHz and a narrowband OOB limit of -80 dBW/700 Hz for ATC downlink operations and uplink operations (applying in the 1559-1605 MHz band for ATC downlink operations and in the 1559-1610 MHz for ATC uplink operations, respectively),<sup>191</sup> and it declined to adopt more restrictive OOB limits that had been proposed by NTIA (which NTIA had indicated were based on use of a 1 dB C/N<sub>0</sub> degradation metric).<sup>192</sup> In 2005, the Commission slightly revised the applicable OOB limits for ATC operations levels—but again did not base those revisions on a 1 dB C/N<sub>0</sub> degradation metric.<sup>193</sup> In sum, the Commission has not used a 1 dB C/N<sub>0</sub> degradation metric as the basis for establishing the technical limits for adjacent band ATC operations to protect GPS device operations within the RNSS allocation. Nor had parties previously raised the need to establish criteria to protect against interference to GPS receivers operating well beyond the bounds of the RNSS spectrum allocation.<sup>194</sup>

<sup>191</sup> *ATC Report and Order*, 18 FCC Rcd at 2028-30, 2049-53, paras.124-127, 176-184. As set out in that order, after January 1, 2005, ATC base stations in the 1525-1559 MHz band were required not to exceed an EIRP in the 1605-1610 MHz band that was determined by the linear interpolation from -70 dBW/MHz at 1605 MHz to -10 dBW/MHz at 1610 MHz for wideband emissions. *See id.* at 2110-13, Final Rules, § 25.253(d)(7), (g)(3).

<sup>192</sup> NTIA proposed OOB levels in the 1559-1610 MHz band for 1525-1559 MHz ATC downlinks of -71 dBm/MHz (-101 dBW/MHz) for wideband emissions and -81 dBm (-111 dBW) for narrowband emissions, and for 1610-1660.5 MHz ATC uplinks of -75 dBm/MHz (-105 dBW/MHz) for wideband emissions and -85 dBm (-115 dBW) for narrowband emissions, which it stated were both based on a 1 dB carrier-to-noise density ratio (C/N<sub>0</sub>) degradation metric that it applied to GPS devices operating in the RNSS bands. *See* Letter from Frederick R. Wentland, Acting Associate Administrator, Office of Spectrum Management, NTIA, to Donald Abelson, Chief, International Bureau, FCC, IB Docket No. 01-185, at 2, Attach. 1 at 4-5, Attach. 2 at 7 (dated Nov. 12, 2002) (posted Mar. 13, 2003). In requesting these OOB limits, NTIA was not requesting that MSS ATC operations within the MSS spectrum had to be limited any further in order to protect GPS operations in the adjacent RNSS allocation. *Id.* at 3-4. The Commission decided not to adopt NTIA's more restrictive proposed OOB limits because the record did not support adoption of OOB levels more stringent than those required of equipment used for Global Mobile Personal Communications by Satellite. *ATC Report and Order*, 18 FCC Rcd at 2052-53, para. 182. The Commission stated that it would coordinate any ATC authority grant with NTIA. *ATC Reconsideration Order*, 20 FCC Rcd at 4642, para. 71.

<sup>193</sup> *ATC Reconsideration Order*, 20 FCC Rcd at 4642-43, para. 72 n.167. The revised OOB limits, more restrictive for ATC base stations but less restrictive for ATC mobile terminals, are -70 dBW/MHz in the 1559-1605 MHz band, and a level determined by linear interpolation in the 1605-1610 MHz band from -70 dBW/MHz at 1605 MHz to -46 dBW/MHz at 1610 MHz, for wideband emissions; and -80 dBW in the 1559-1605 MHz band, and a level determined by linear interpolation in the 1605-1610 MHz band from -80 dBW at 1605 MHz to -56 dBW at 1610 MHz, for narrowband emissions of less than 700 Hertz bandwidth. 47 CFR §§ 25.253(d)(9), (g)(3).

<sup>194</sup> We note that the International Telecommunication Union (ITU) recommends that the 1 dB IPC be used in certain situations, but it has *not* recommended that a 1 dB IPC be used with respect to setting the maximum power levels for services that operate *outside* the band(s) allocated for a radiocommunication service. For example, the ITU recommends that a 1 dB IPC be used to set the maximum acceptable power levels of interference emissions (i.e., OOBs) that fall *inside* the bands allocated for a variety of radiocommunication services (e.g., radars, GPS). *See, e.g.,* Recommendation ITU-R M.1460-2 (02/2015), Technical and operational characteristics and protection criteria of radiodetermination radars in the frequency band 2900-3100 MHz at 20, Annex 2, Protection criteria for radars; Recommendation ITU-R M.1903 (01/2012), 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 1559-1610 MHz at 9, Section 2.3, Assisted RNSS (A-RNSS) receivers (Recommendation ITU-R M.1903). For commercial grade handheld and assisted RNSS receivers, the ITU has used the 1 dB IPC to set forth maximum power levels of aggregate narrow-band (< 700 Hertz bandwidth) and wideband (> 1 megahertz bandwidth) interference emissions in the 1560.075-1590.765 MHz portion of the 1559-1610 MHz band. *See*

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51. The Commission has adopted emission limits applicable to unlicensed and licensed emissions that fall within the 1559-1610 MHz RNSS allocation. In its 2002 proceeding on ultra-wide band (UWB) devices overlapping the RNSS allocation, the Commission adopted emissions limits based on what NTIA thought necessary (which NTIA based on a 1 dB increase in the noise floor of GPS receivers), and did so considering that the parties had been unable to agree on the emission levels. The Commission further stated, however, that it viewed those emissions levels as “extremely conservative” and “unique to [that] proceeding and will not be considered as a basis for determining or revising standards for other radio frequency devices.”<sup>195</sup> We also note that the Commission adopted specific emissions limits on certain wireless or broadcast services operating in much lower frequency bands to address potential harmful interference concerns that the second and third harmonics of those services that fall inside the 1559-1610 MHz RNSS allocation could interfere with GPS receivers; in these proceedings, the Commission established specific limits on the transmissions that fell into the 1559-1610 MHz RNSS allocation.<sup>196</sup>

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Recommendation ITU-R M.1903 at 14-15, Table 2, Column 7, A-RNSS and Note 1. For interference bandwidths greater than 1 megahertz, the interference power spectral density shall not exceed the pertinent wideband threshold listed in Table 2 of Rec. ITU-R M.1903 over the frequency range  $1575.42 \pm 10$  MHz. *Id.* at 11, Table 1.

<sup>195</sup> See *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Docket No. 98-153, First Report and Order, 17 FCC Rcd 7435, 7436-37, paras. 1-2 (2002) (*Ultra-Wideband Order*). Specifically, the UWB device emission limits with respect to the 1559-1610 MHz, 1164-1215 MHz, and 1215-1240 MHz RNSS bands are -95.3 or -105.3 dBW/MHz for wideband noise-like signals, depending on the particular UWB application, and -75.3 or -85.3 dBW/MHz for narrowband signals. See *id.* at 7511-13, paras. 222-225; 47 CFR §§ 15.509(d), (e), 15.510(c)(4), (5), 15.513(d), (e), 15.515(d), (e), 15.521(c), (d). While the 2002 *Ultra-Wideband Order* did not expressly discuss the 1 dB issue, the Commission subsequently noted in its 2003 Order on Reconsideration that the emissions limits that it had adopted in 2002 were based on conservative models requested by NTIA, the Department of Defense, and the US GPS Industry Council, which in turn were based on a 1 dB increase in the noise floor of the GPS receiver. *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Docket No. 98-153, Memorandum Opinion and Order and Further Notice of Proposed Rule Making, 18 FCC Rcd 3857, 3863, para. 12 (2003).

<sup>196</sup> In 2000, the Commission adopted OOB emissions limits on wireless licensees operating in the 746-758 MHz, 775-788 MHz and 805-806 MHz bands because the second harmonic could fall in or near the 1559-1610 MHz RNSS allocation where GPS devices operate in order to protect them from harmful interference. Specifically, it adopted OOB limits on emissions into the 1559-1610 MHz RNSS band of -70 dBW/MHz for wideband signals and -80 dBW EIRP for discrete emissions of less than 700 Hz bandwidth. See *Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State and Local Public Safety Agency Communications Through the Year 2010*, WT Docket No. 96-86, Third Memorandum Opinion and Order and Third Report and Order, 15 FCC Rcd 19844, 19877-80, paras. 75-81 (2000); see also 47 CFR § 27.53(f). In 2004, the Commission adopted OOB limits on LPTV and TV translator stations using frequencies in the 518-536 MHz, 602-608 MHz, and 614-620 MHz to prevent second and third harmonics from causing harm to GNSS services in the 1559-1610 MHz band as well as the 1164-1215 MHz and 1215-1240 MHz RNSS bands. See *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television, Television Translator, and Television Booster Stations and Amend Rules for Digital Class A Television Stations*, MB Docket No. 03-185, Report and Order, 19 FCC Rcd 19331, 19402-04, paras. 220-222 (2004) (*Digital LPTV Order*); 47 CFR § 74.794(b) (LPTV and TV translator transmitters must include filtering with an attenuation of not less than 85 dB into these RNSS bands). These particular emissions limits, however, were not based on the Commission's determination that such limits were necessary to protect against harmful interference, and instead were based on an agreement between LPTV/TV translator representatives and the U.S. GPS Industry Council as well as the ready availability of filters that met this requirement. See *Digital LPTV Order*, 19 FCC Rcd at 19404, para. 222. The analysis used for developing the filters was based on use of an interference-to-noise (I/N) ratio criterion of -6 dB used in the NTIA analysis, which is equivalent to a 1 dB increase in the noise floor, which equates to a 1-dB decrease in the  $C/N_0$ . See *id.* at 19403-04, paras. 221 n.460 (page A-7, Sec. 3.1.1.2.2 of the NTIA submission cited specifically refers to the interference-to-noise (I/N) ratio criterion of -6 dB used in its analysis to develop the LPTV filtering required, which the

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52. Use of the 1 dB metric for protecting GPS receivers from the possibility of interference, in the manner proposed by commenters, would be inappropriate. Advocates of this approach argue that a 1 dB metric should be applied to GPS receivers not only with respect to these receivers' in-band operations (i.e., their operations within the RNSS allocation), but also for all GPS receivers that may experience overload interference by picking up transmissions that fall outside of the RNSS allocation (including Ligado's proposed transmissions in the 1526-1536 MHz portion of the MSS band, separated by 23 megahertz from the RNSS band edge). In contrast, Ligado asserts that NTIA and the Air Force long ago agreed that GPS receivers were not entitled to protection outside of their designated band,<sup>197</sup> a contention that NTIA has not refuted. We observe that, aside from the matter of whether a 1 dB  $C/N_0$  degradation metric is an appropriate indicator of harmful interference, there are variations in this metric even without any signal from Ligado. A receiver may experience a 1 dB degradation in the  $C/N_0$  as a natural occurrence relative to the GPS satellite signals that are in view, unrelated to the introduction of additional transmissions. For example, the GPS Interface Specification, 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.<sup>198</sup>

53. In addition, the accuracy of the  $C/N_0$  estimators as implemented in GPS receivers is not traceable to any known standard. Indeed, there are several different algorithms known to be used for *estimating* the noise power density used to determine the  $C/N_0$ .<sup>199</sup> Some studies have been performed to examine the estimation bias of at least five different algorithms used for estimating the  $C/N_0$ : (1) Beaulieu's method, (2) the signal-to-noise variance (SNV) model, (3) the moments method (MM), (4) the real signal-complex noise (RSCN) model, and (5) the narrowband-wideband power ratio (NWPR) method.<sup>200</sup> The NASCTN Report is the only one of the three recent efforts that includes an examination of the variabilities and biases associated with each of these different  $C/N_0$  estimators. Appendix B of the NACSTN Report provides data from this examination which demonstrates that under conditions similar to those imposed in the tests (e.g., simulated low satellite power levels resulting in a low initial  $C/N_0$ ), the variability (error) in reported  $C/N_0$  can be significant, as much as 2-3 dB.<sup>201</sup> The NASCTN Report shows

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Commission adopted). The Commission stated that these harmonics emissions limits "will adequately protect the various RNSS operations," and made clear that this filtering requirement does not apply to other possible sources of emissions into the RNSS allocations. *Id.* at 19404, para. 222 & n.462 (specifically citing, as an example, the OOBE limits that the Commission adopted in 2002 for MSS mobile earth stations).

<sup>197</sup> See Ligado July 19, 2018 Reply at 18. Specifically, Ligado asserts that GPS BLKIII Satellite Payload Spectrum Certification JF 12/09603 reflects that NTIA and the Air Force had agreed that GPS receivers were not entitled to protection for a bandwidth of greater than 24 megahertz (extending from 1563-1587 MHz), which falls outside of the spectrum bands in which Ligado would be operating. *Id.* at 18-19; *see also* Ligado Nov. 21, 2019 *Ex Parte* at 6; Ligado Apr. 12, 2020 *Ex Parte* at 9-10.

<sup>198</sup> 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.fcc.gov/technical/icwg/IS-GPS-200H.pdf>.

<sup>199</sup> Inside GNSS, *Are Carrier-to-Noise Algorithms Equivalent in All Situations?* (Jan. 8, 2010), <https://insidengss.com/are-carrier-to-noise-algorithms-equivalent-in-all-situations>.

<sup>200</sup> Emanuela Falletti, Marco Pini, and Letizia Lo Presti, *Low Complexity Carrier-to-Noise Ratio Estimators for GNSS Digital Receivers*, 47 IEEE Transactions on Aerospace and Electronic Systems 420, 420-437 (Jan. 2011).

<sup>201</sup> See NASCTN Report at 274, § B.3. The data show that for the signal-to-noise variance (SNV) model, the  $C/N_0$  reported is inaccurate by 1 dB in more than 50% of the trials and by 2 dB in nearly 25% of the trials. It further shows that for Beaulieu's model, the reported  $C/N_0$  is in error by 2 dB more than 50% of the time and by 3 dB more

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that these results “indicate that under some conditions, there may be differences between distributions of  $C/N_0$  estimators. Such differences would indicate variations that could be expected due to the choice of an  $C/N_0$  estimation algorithm.”<sup>202</sup> 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  $C/N_0$ .<sup>203</sup> We note that the data in the NASCTN Report also indicate that a 1 dB  $C/N_0$  reduction does not correlate to any significant error in a GPS device’s reporting of position or to an increase in time-to-first-fix,<sup>204</sup> and thus we reject the GPS Innovation Alliance’s contrary contention that the report supports use of a 1 dB  $C/N_0$  degradation standard for determining harmful interference.<sup>205</sup> Similarly, we note that data in the RAA testing also indicate that a 1 dB  $C/N_0$  degradation does not correlate to any significant error in a GPS device’s reporting of position.<sup>206</sup>

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  $C/N_0$ . 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.<sup>207</sup>

55. The DOT ABC Report states, and we agree, that “[t]here are multiple interference mechanisms that can degrade  $C/N_0$  of a GPS receiver.”<sup>208</sup> The report states, further, that “it is difficult to

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than 25% of the time. For both of these implementations, the data show that the  $C/N_0$  estimator provides erroneous  $C/N_0$  estimates more frequently than it provides accurate ones. The other  $C/N_0$  estimator algorithms, although they show less variance, nonetheless indicate erroneous estimates in a significant number of the trials.

<sup>202</sup> NASCTN Report at 275, § B.4.

<sup>203</sup> See *id.* at 146, § 6, Fig. 6.25; *id.* at 126, § 6, Fig. 6.5; and *id.* at 131, § 6, Fig. 6.10, respectively. These charts demonstrate the variability in the accuracy of the  $C/N_0$  estimator.

<sup>204</sup> See *id.* at 223-232, 236-246.

<sup>205</sup> As noted above, the GPS Innovation Alliance contends that because the NASCTN Report shows a performance degradation in time to first fix within approximately 3 dB of the 1 dB  $C/N_0$  degradation point, there is a clear connection between signal reception (measured by  $C/N_0$ ) and the user experience, and that every dB of  $C/N_0$  is valuable. See GPS Innovation Alliance July 13, 2017 *Ex Parte*; GPS Innovation Alliance Feb. 18, 2020 *Ex Parte* at 2-3; see also *supra* note 171. Degradations in GPS device performance caused by a decrease in  $C/N_0$  that is 3 dB or more greater than a 1 dB decrease does not establish support for the use of a 1 dB  $C/N_0$  reduction standard for determining whether there is harmful interference to GPS devices. In addition, as we discuss above, the NASCTN Report includes data showing that the variability in reported  $C/N_0$  can be as much as 2-3 dB, thereby providing further evidence of the unreliability of using a 1 dB  $C/N_0$  degradation metric as a standard for determining harmful interference.

<sup>206</sup> See, e.g., May 2016 RAA Report at 4-5, 13 and Appx. A at 61-62; see also Ligado June 6, 2016 Reply, Attach. B (Mark Sturza submission, “Changes in  $C/N_0$  are not a Reliable Indicator of KPI Impact”).

<sup>207</sup> As discussed above, the NASCTN Report developed a test plan designed to ensure the integrity of the measurements and to quantify the measurement uncertainties. See *supra* para. 38.

<sup>208</sup> DOT ABC Report at 45.



isolate the specific interference mechanism for each GPS receiver without sufficient technical information, such as receiver design, radio frequency filter selectivity, [and] low noise amplifier gain” (among other information).<sup>209</sup> The DOT ABC Report does not address receiver design or filter selectivity in its findings. The underlying data in the report, however, show extremely wide variation in the susceptibility of GPS receivers in most categories to signals outside the RNSS spectrum allocation (as assessed under a 1 dB C/N<sub>0</sub> degradation metric). For instance, the susceptibility difference in high-precision receivers to an LTE signal in the bands adjacent to the 1559-1610 MHz band varied by as much as 62 dB (from a lower bound LTE power level of -72 dBm (which is equivalent to -102 dBW) to an upper bound LTE power level of -10 dBm (equivalent to -40 dBW)), and general location/navigation devices varied by as much as 50 dB (from a lower bound LTE power level of -60 dBm (equivalent to -90 dBW) to an upper bound LTE power level of -10 dBm).<sup>210</sup>

56. This extreme variation in performance indicates that it is technically feasible to design GPS receivers that have relatively strong immunity to signals outside the RNSS allocation. We know that receiver design and selectivity can make an important difference. As discussed elsewhere, the RAA Reports conclude that where receivers are potentially affected, such as high-precision receivers, replacing the antenna could result in elimination of some performance issues,<sup>211</sup> while the NASCTN Report similarly shows that using different antennas can result in significantly better ability to avoid interference from Ligado’s proposed operations.<sup>212</sup> In evaluating harmful interference issues concerning the compatibility of adjacent band operations, understanding receiver design and filter selectivity is important, particularly with regard to receiver overload interference in this proceeding insofar as a particular receiver may include a front-end filter that receives signals (whether GPS or some other signals) that fall well outside of the RNSS allocation.

57. Our review of tables summarizing the DOT ABC Report’s findings also indicates the problematic nature of those findings. We note, for example, that application of the proposed 1 dB C/N<sub>0</sub> degradation IPC to fundamental emissions, as proposed in its report, would limit the output power from an ATC base station or mobile terminal transmitter operating in the spectrum adjacent to the RNSS allocation to less than 1/1000<sup>th</sup> of a Watt, less than the power of a Bluetooth device.<sup>213</sup> Since Ligado

<sup>209</sup> DOT ABC Report at 45 (“it is difficult to isolate the specific interference mechanisms for each GPS receiver without sufficient technical information, such as receiver design, radio frequency filter selectivity, low noise amplifier gain, noise figure, 1 dB gain compression point and third-order intercept point from the GPS receiver manufacturers”). DOT notes that participation by GPS/GNSS manufacturers was voluntary, and that they were under no obligation themselves to provide this type of technical information. *Id.*

<sup>210</sup> See *Id.* at Appx. B, Aggregate ITM Results at 34, Fig. B-25: 10 MHz GPS L1 C/A Statistical Mask Results for General Location Navigation receivers, and 36, Fig. B-27: 10 MHz GPS L1 C/A Statistical Mask Results for High Precision receivers, <https://www.transportation.gov/sites/dot.gov/files/docs/subdoc/176/dot-gps-adjacent-band-final-reportappendixathruf.pdf>. We note that the cellular category, which is in effect governed by the 3GPP standard for cellular devices, is the only category showing minimal variation with respect to signals in the bands adjacent to the 1559-1610 MHz band (4 dB). *Id.* at 32, Fig. B-21: 10 MHz L1 C/A Statistical Mask Results for Cellular receivers.

<sup>211</sup> See June 2016 RAA Report at 17.

<sup>212</sup> See *infra* discussion at para. 80 and note 280 (discussing improvements to susceptibility where high-precision receivers’ antennas were replaced with a more spectrally efficient antenna).

<sup>213</sup> See DOT ABC Report at 104, Table 4-6 (column 1530) & 106, Table 4-8 (column 1630). Table 4-6 shows that a Ligado base station implemented in a micro-urban deployment will increase the noise density of a high-precision GPS receiver channel by 1-dB when transmitting at an EIRP level of -41.08 dBW. Table 4-8 shows that a Ligado handset transmitting at an EIRP level of -31.3 dBW will increase the noise density by 1-dB in a high-precision GPS receiver channel. An EIRP level of -41.08 dBW is equivalent to 0.078 ( $10^{(-41.08+30)/10}$ ) milliwatts and an EIRP level of -31.3 dBW represents 0.74 ( $10^{(-31.3+30)/10}$ ) milliwatts, both of which are less than 1/1000<sup>th</sup> of a Watt (i.e., less than a milliwatt). For comparison, typical Bluetooth (BT) devices transmit at EIRP levels between 4 dBm (2.5 milliwatts) for Class 2 operation and 20 dBm (100 milliwatts) for Class 1 operation.

would be operating ATC base stations in the 1526-1536 MHz band, which is separated by more than 20 megahertz from the RNSS band edge, this limitation is clearly the result of GPS devices receiving signals far outside of the lower edge of the RNSS allocation (i.e., overload interference from far outside of the RNSS allocation). Such a limitation would doubly guarantee that *all* GPS receivers will be protected against harmful interference—no matter how poorly designed or how far outside of the RNSS allocation that they are operating. But it would also effectively prevent the deployment of any terrestrial transmitters or networks with any reasonable frequency separation from the allocation where GPS operates. We also strongly disagree that interference protections should be based on the worst performing receivers, and this is the basis for the interference protection levels in the DOT ABC Report. Taking such an approach would undermine our ability to promote efficient use of our spectrum resources and achieve our spectrum management goals.

58. We also observe that application of the 1 dB  $C/N_0$  criterion would conflict with our precedent and assume harmful interference even when harmful interference has been disproven. For example, under the 1 dB  $C/N_0$  criterion even the cellular category would be predicted to experience interference from Ligado's proposed operations. Testing of cellular devices going back to 2011, however, has determined that cellular receivers did not experience any interference (a finding that NTIA acknowledged in 2012).<sup>214</sup> We also observe that not one of the ATC terrestrial base stations that were contemplated for ATC operations under the Commission's ATC decisions—coordinated with NTIA when the Commission established the ATC rules—could have met this criterion.<sup>215</sup>

59. In sum, we find that the application of a 1 dB  $C/N_0$  as a measurand is not appropriate given that the  $C/N_0$  estimators are not capable of accurately and reliably discerning a 1 dB change in the  $C/N_0$ . In addition, the 1 dB  $C/N_0$  degradation criterion represents an interference protection criterion, not an assessment of harmful interference or an evaluation of performance (or performance degradation). The difference is the large built-in protection margin, which is significant and overly conservative, as is demonstrated in the data from the various tests. Furthermore, when the 1dB IPC is applied to fundamental emissions beyond the RNSS-allocated band, the "protection criterion" in effect blurs the responsibility of the receiver itself to incorporate a reasonable degree of adjacent-channel rejection in its design.<sup>216</sup> Moreover, with the 1 dB  $C/N_0$  degradation approach, there is no connection presented in the technical studies available that shows how a 1 dB decrease in  $C/N_0$  relates to performance-based metrics such as position accuracy, and therefore provides no demonstrable evidence of how the functioning of the RNSS receiver is endangered, seriously degraded, or repeatedly interrupted.

#### **D. Potential Harmful Interference Concerns**

60. In examining Ligado's 2015 license modification applications, as amended in 2018, we consider whether Ligado's proposed terrestrial operations—specifically in the 1526-1536 MHz portion of

<sup>214</sup> NTIA Feb. 14, 2012 Letter at 3.

<sup>215</sup> The data in the DOT ABC Report show a maximum power level below 1525 MHz of -10 dBm (-40 dBW) (less than 1/1000 of a Watt). See, e.g., DOT ABC Report, Appx. B at 32, Fig. B-21, and 33, Fig. B-23. The ATC rules adopted in 2003 permitted a base station peak EIRP in the 1525-1559 MHz band of 19.1 dBW/200 kHz per carrier, with no more than 3 carriers per sector, not to exceed 14.1 dBW/200 kHz towards the physical horizon (not to include man-made structures). *ATC Report and Order*, 18 FCC Rcd at 2110, § 25.253(d)(1), (2). In 2005, the ATC rules were modified to allow a base station EIRP of  $31.9 - 10 \cdot \log(\text{number of carriers})$  dBW/200 kHz per sector for each carrier in the 1525-1541.5 MHz and 1547.5-1559 MHz frequencies. *ATC Reconsideration Order*, 20 FCC Rcd at 4679, § 25.253(d)(1)-(4). We also note that, if DOT's proposed IPC were used, the incumbent aeronautical mobile telemetry (flight testing) operations in the 1435-1525 MHz band below the MSS band, which operate at a transmitter power of up to 25 Watts, would not be permitted. See 47 CFR § 87.131 n.3.

<sup>216</sup> NTIA has noted the need to "stri[k]e the right balance between interference caused by transmitters and performance of GPS receivers" so as to promote the full use of the spectrum resource. NTIA Feb. 14, 2012 Letter at 6; see discussion *supra*.

its MSS downlink band and in the 1627.5-1637.5 and 1646.5-1656.5 MHz portions of its MSS uplink band—sufficiently address concerns about potential harmful interference both to GPS operations in the 1559-1610 MHz RNSS band and to other MSS operations, whether co-channel or adjacent to Ligado’s proposed operations. Our focus on *harmful* interference is important, and necessary to ensure that the spectrum resource is managed efficiently and effectively.<sup>217</sup>

61. We base our findings on technical information in the record that evaluates potential harmful interference from Ligado’s proposed operations to GPS devices using performance-based metrics and analysis. In reaching our conclusions on cellular, general location/navigation, general non-certified aviation, and high-precision devices, we focus predominantly on the substantial record and two sets of tests that have been conducted subsequent to Ligado’s 2015 license modification applications—the 2016 RAA Reports and the 2017 NASCTN Report. For certified aviation GPS receivers, we rely on the performance-based standard and analyses conducted by the FAA and presented in the 2018 DOT ABC Report. Where relevant and appropriate, we also draw from the earlier record and tests.

62. The record before us demonstrates that it is both technically possible and feasible for Ligado’s proposed low power base station transmitters to operate in the lower portion of the MSS band adjacent to the RNSS allocation without causing harmful interference to GPS operations. The agreements Ligado has reached with major GPS receiver manufacturers, as well as support from other receiver or component manufacturers, reinforce the conclusion of our technical analysis that GPS receivers can co-exist with low power terrestrial transmitters with frequency separation within the spectrum block adjacent to the RNSS allocation, and that future devices entering the market can co-exist with Ligado’s proposed terrestrial operations, without experiencing harmful interference. The GPS receiver manufacturers have entered into these co-existence agreements and provided their support for Ligado’s license modification application as amended, establishing that co-existence is possible and feasible under the technical terms of the agreements, including the condition that the manufacturers are notified in advance of Ligado’s station deployments. The record additionally demonstrates that it is technically possible to make modifications to receivers to remedy harmful interference through retrofitting or replacement of antennas. We observe that where there are standards in place (as is the case for certified aviation receivers), we have greater assurance that low power transmitters in spectrum adjacent to the RNSS allocation will not cause harmful interference to GPS receivers. Where we do not have the benefit of international and/or domestic standards, as is the case of all receivers other than certified aviation receivers, we rely on the co-existence agreements and the testing results on GPS device performance as supplied in the record.

63. Finally, with respect to other MSS operations, Ligado has entered into an arrangement with Inmarsat, which operates co-channel with Ligado in the 1525-1559 MHz band, to address potential interference concerns. Ligado also has endeavored to address potential interference concerns Iridium has raised related to Iridium’s adjacent MSS operations, but the two parties have not reached an understanding. Absent an understanding between the parties, we reduce Ligado’s emissions within the frequency band used by Iridium and encourage the parties to engage in further discussions to reach mutually satisfactory arrangements where possible.<sup>218</sup>

### **1. Concerns regarding harmful interference to adjacent band GPS operations**

64. In its 2018 Amendment, Ligado amended its 2015 license modification applications with respect to its proposed terrestrial downlink operations at 1526-1536 MHz, both lowering significantly the proposed power levels (to 9.8 dBW from 32 dBW) and proposing that the Commission adopt additional

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<sup>217</sup> See also NTIA’s Manual of Regulations and Procedures for Federal Radio Frequency Management (2017), § 6.1.1, Special Terms (General), [https://www.ntia.doc.gov/files/ntia/publications/redbook/2017-09/6\\_17\\_9.pdf](https://www.ntia.doc.gov/files/ntia/publications/redbook/2017-09/6_17_9.pdf) (definition of “harmful interference”).

<sup>218</sup> See *infra* paras. 116-119.

conditions on the deployment and operation of its downlink base stations.<sup>219</sup> Ligado asserts that this amendment ensures that its proposed operations “will fully protect certified aviation receivers.”<sup>220</sup> Ligado states that this amendment fulfills its commitment in its 2015 license modification applications to condition its proposal on limiting the power in the 1526-1536 MHz band to levels necessary to achieve compatibility with current or future standards developed by the FAA to protect certified aviation GPS receivers.<sup>221</sup> In addition, as discussed above, Ligado contends that the proposed 9.8 dBW power level (which is more than a 99.3% reduction from the 32 dBW maximum proposed in its 2015 license modification application) will benefit all GPS receivers, and that Ligado’s co-existence agreements with major GPS device manufacturers and the extensive empirical testing of other GPS receivers assures protection of all other categories of GPS devices.<sup>222</sup>

**a. Certified aviation GPS receivers**

65. Certified aviation receivers are critical to air safety, and it would be a significant matter if aircraft would need to be retrofitted in any way, as it could take at least a decade to retrofit aircraft with new equipment and have them recertified by the FAA.<sup>223</sup> As explained earlier, Ligado worked with the FAA to define the operating scenarios necessary to protect certified aviation receivers from receiving harmful interference.<sup>224</sup> Several commenters support this approach.<sup>225</sup> Ligado submits that the FAA appropriately based its analysis on the principle that certified aviation GPS receivers “meet their performance requirements when operating within the RF interference environment defined in appropriate FAA Technical Standard Orders (TSOs).”<sup>226</sup>

66. The FAA’s “assessment zone” approach in its analysis sets the maximum EIRP for a tower at the level that protects certified aviation GPS receivers operating at any point outside a “standoff cylinder” with a 250-foot radius from the subject tower and extending 30 feet above the antenna.<sup>227</sup> This methodology would result in a maximum EIRP in the 1526-1536 MHz band of 13 dBW, with a lower EIRP required under certain circumstances depending on the specific attributes of a particular site (such as antenna height and downtilt angle), and inclusive of system-wide limitations (such as additional reductions to account for aggregation).<sup>228</sup> The DOT ABC Report concluded that the Helicopter Terrain

<sup>219</sup> Ligado May 31, 2018 *Ex Parte* at 1-3.

<sup>220</sup> Ligado May 31, 2018 *Ex Parte*, Amendment at 5.

<sup>221</sup> *Id.* at 1.

<sup>222</sup> *Id.* at 2-3; Ligado Amendment at 5.

<sup>223</sup> See TWG Final Report at 16, § 2.7.1 (noting that aviation representatives believe the retrofitting process would take at least 8-10 years).

<sup>224</sup> See *supra* para. 14.

<sup>225</sup> See, e.g., Letter from Doug Brake, Director, The Information Technology and Innovation Foundation, to Marlene Dortch, Secretary, FCC, IB Docket No. 11-109, at 1-3 (filed July 9, 2018) (supporting Ligado’s collaboration with the FAA to protect certified aviation receivers); Letter from Paul A. Roberts, Vice President, American Tower Corporation, to Marlene Dortch, Secretary, FCC, IB Docket No. 11-109, at 1 (filed July 16, 2018) (noting how Ligado’s amendment to its license modification application addresses concerns over possible interference with certified aviation GPS receivers); Letter from Stephen A. Wilkus, CTO and Managing Partner, Spectrum Financial Partners, LLC, to Marlene Dortch, Secretary, FCC, IB Docket No. 11-109, at 1-2 (filed July 9, 2018) (supporting Ligado’s proposal to limit its low band (i.e., base stations) EIRP to address interference concerns with respect to certified aviation receivers).

<sup>226</sup> Ligado May 31, 2018 *Ex Parte*, Ligado Amendment at 3 n.9 (quoting DOT ABC Report at II).

<sup>227</sup> DOT ABC Report at VI-VII.

<sup>228</sup> May 31, 2018 *Ex Parte*, Ligado Amendment at 3.

Awareness Warning System (HTAWS) scenario, the most restrictive of the certified aviation scenarios the FAA examined, requires a downlink EIRP limit of 9.8 dBW (10 W) (cross-polarized) at 1531 MHz and minimum inter-station separation distance of 433 meters (1420.6 feet) for fixed location base stations in a hexagonal grid to protect from harmful interference certified aviation GPS receivers operating in accordance with applicable MOPS.<sup>229</sup> DOT notes that “[t]he FAA has not completed an exhaustive evaluation of the operational scenarios in developing this assessment zone. Further, the current analyses do not include an operational assessment of the impact of the assessment zone in densely populated areas. For example, the risk posed to people and property for operations such as unmanned aircraft systems (UAS) using certified avionics may be significant as such aircraft may be required to operate within the assessment zone.”<sup>230</sup> With respect to the potential impact of handsets’ uplink transmissions above 1626.5 MHz to certified aviation devices, DOT evaluated several aircraft scenarios and concluded that “[t]he ‘Handset’ cases assessed showed these do not present a limiting case or scenario for certified aviation receivers.”<sup>231</sup>

67. Consistent with the FAA’s analysis that certified aviation receivers not exceed 9.8 dBW, included as a part of the DOT ABC Report, Ligado amended its 2015 license modification applications. Specifically, this amendment would: (1) require that Ligado’s ATC base stations operating at 1526-1536 MHz band not exceed an EIRP of 9.8 dBW (10 W) with a +/- 45 degree cross-polarized base station antenna, consistent with the FAA’s analysis for certified aviation receivers in its 2018 DOT ABC Report; (2) prohibit any Ligado base station antenna in this downlink band from operating at any location less than 250 feet laterally or less than 30 feet below an obstacle clearance surface established by the FAA; and (3) require Ligado to comply with specified reporting requirements to the Commission and FAA, and with other notification and monitoring obligations.<sup>232</sup> Ligado indicates that it will comply with the network density parameters and minimum inter-station distance of 433 meters (1420.6 feet) set forth in the DOT Report.<sup>233</sup> Ligado underscores that the underlying analysis and conclusions regarding protection for certified aviation receivers are properly based on evaluating whether these receivers meet their performance requirements.<sup>234</sup> As noted above, Ligado states that these operating parameters are consistent with the tolerable interference levels developed by the FAA and RTCA, and endorsed in the

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<sup>229</sup> DOT ABC Report at VI, 153, 154, Tbl. 5-9, and 158. The FAA’s analysis of Ligado’s proposed operations assumed that base stations were located in a hexagonal grid with a 433 meter (1420.6 feet) or 693 meter (2273.6 feet) inter-station distance. *Id.* at 144, Tbl. 5-5.

<sup>230</sup> *Id.* at VII and 120.

<sup>231</sup> *Id.* at 152-53; *see also id.* at VI, 118-20, and 149.

<sup>232</sup> Ligado May 31, 2018 *Ex Parte* at 1-2; Ligado Amendment at 6. The specific reporting, monitoring, and notification requirements Ligado proposed are as follows: at least 30 days before commencing transmissions at a base station site, Ligado to submit to the FCC and FAA: Location of the proposed base station antenna site (latitude and longitude); to be submitted confidentially, access governed by FCC standard rules (e.g., available pursuant to confidentiality order); base station antenna radiation center height above ground level; base station antenna tilt for both mechanical and electrical tilt; base station antenna specifications, including polarization and pattern. Ligado Amendment at 6. To ensure compatibility with 14 CFR Part 77, no tower to be located such that 250’ standoff cylinder would pierce the obstacle clearance surface. *Id.* Ligado to maintain network operations center procedures for continuous monitoring of the transmit power for each base station site; Ligado to maintain a toll-free telephone number for the public to report relevant apparent incidences of interference from Ligado’s operations in the Lower Downlink Band (i.e., 1526-1536 MHz) to GPS; if Ligado receives a credible report of interference in the Lower Downlink Band, Ligado to investigate and rectify interference operations as needed; Ligado to notify FCC of any such event. *Id.*

<sup>233</sup> Ligado July 26, 2018 Further Reply Comments at 8.

<sup>234</sup> Ligado May 31, 2018 *Ex Parte*, Ligado Amendment at 3 n.9. *See also* DOT ABC Report at II, 118-120, 152-154 (discussing certified aviation receiver interference analysis by the FAA and RTCA).

DOT ABC Report, for purposes of protecting certified aviation GPS receivers from harmful interference.<sup>235</sup> Ligado asserts that, in establishing the EIRP level as low as 9.8 dBW, the FAA and DOT are using a conservative propagation model to protect certified aviation receivers.<sup>236</sup> In comments, 3C Systems Company asserts the Ligado's proposed network would not result in harmful interference to certified aviation receivers.<sup>237</sup>

68. A group of aviation organizations (including the Air Line Pilots Association International, Airlines for America, National EMS Pilots Association, Professional Helicopter Pilots Association, Association of Air Medical Services, and the Airborne Public Safety Association) (referenced herein as "Aviation Group") and Aviation Spectrum Resources, Inc. (ASRI) both contend that Ligado's amended applications at the reduced power level still present significant safety and operational problems for those in the aviation community that rely on certified aviation GPS receivers.<sup>238</sup> ASRI states that Ligado misconstrues the FAA's assessment that indicates that some helicopter operations need additional protection and that additional studies are necessary. In particular, it points to language in the DOT ABC Report noting that while the report assumes a 250-foot "assessment zone" in its analysis, the FAA "has not completed an exhaustive evaluation of the operational scenarios in developing this assessment zone,"<sup>239</sup> and, as stated in the DOT ABC Report, "plainly falls short of an acceptance of Ligado's operational proposal regarding the 500-foot diameter standoff cylinder."<sup>240</sup> ASRI also states that the DOT ABC Report makes clear that the FAA has not completed its evaluation on certified aviation receivers with respect to helicopters and to UAS.<sup>241</sup> Furthermore, ASRI states that Ligado's proposed procedures would provide insufficient notification to aircraft operators of new and modified Ligado base stations,<sup>242</sup> and "[w]ithout readily knowing accurate and timely details on where Ligado base stations operate, low-level aircraft operating outside of Part 77 obstacle areas would be subject to unexpected harmful interference to GPS."<sup>243</sup> On the other hand, Metro Aviation (Metro), a leading provider of air medical services that operates more than 130 rotary and fixed-wing aircraft in 20 states, represents that it is confident that Ligado's proposed operations will not interfere with the safe operation of helicopters. It concludes that Ligado's proposed standoff cylinder will protect safe helicopter operations, especially given that under the FAA's visual flight rules, operations within 500 feet of an object require flight by

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<sup>235</sup> Ligado May 31, 2018 *Ex Parte* at 1 (citing DOT ABC Report at 118-19, 149, 152-53 (concluding EIRP limit of 9.8 dBW (10W) at 1531 MHz will protect certified aviation receivers installed in helicopters operating in accordance with applicable existing MOPS)).

<sup>236</sup> May 31, 2018 *Ex Parte*, Ligado Amendment at 3-4; Ligado July 9, 2018 Comments at 2.

<sup>237</sup> 3C Systems Company July 6, 2018 Comments at 1-3.

<sup>238</sup> Letter from Aviation Group to Daniel K. Elwell, Acting Administrator, FAA, IB Docket No. 11-109, at 1-3 (dated June 15, 2018) (filed June 18, 2018); ASRI Comments on Amendment to the Applications of Ligado Networks LLC at 1-8 (filed July 9, 2018) (ASRI July 9, 2018 Comments). We note that ASRI also opposed Ligado's 2015 license modification applications. See Letter from Edward A. Yorkgitis, Counsel to ASRI, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, 12-340, at 1-3 (filed Aug. 4, 2017) (citing and attaching Letter from John Stenbit, Chair, National Space-based PNT Advisory Board, to Deputy Secretary of Defense Robert O. Work and Deputy Secretary of Transportation Jeffrey A. Rosen, Co-Chairs, PNT EXCOM (July 5, 2017)).

<sup>239</sup> ASRI July 9, 2018 Comments at 5 (quoting the DOT ABC Report at 120).

<sup>240</sup> *Id.*

<sup>241</sup> *Id.*

<sup>242</sup> *Id.* at 6.

<sup>243</sup> *Id.*

visual reference rather than relying on instruments, including GPS.<sup>244</sup> Metro also states that Ligado's proposed operations will assist the aviation industry by providing much-needed services that facilitate aviation operations, such as facilitating the delivery of key patient data to the hospital while the aircraft is *en route* transporting a patient to the hospital.<sup>245</sup>

69. Another group of organizations that rely on GPS, satellite communications services, and weather and environmental data (including AccuWeather, the Civil Aviation Aerospace Industries Association, NENA the 911 Association, the National Air Transportation Association, and the Resilient Navigation and Timing Foundation) (referenced herein as "GPS/SATCOM Coalition") also oppose Ligado's proposal, contending there would be harm to certified aviation receivers.<sup>246</sup> Garmin is concerned that if the base station siting density is increased beyond the level assumed in the original analysis without any compensating adjustments to the power levels, certified aviation devices would likely experience harmful interference; it asserts that restrictions on the spacing of towers/transmitters and antenna parameters (e.g., height, downtilt, polarization) should accompany any grant of Ligado's proposal.<sup>247</sup> Garmin also comments that the concerns and safety issues of the industry have not been addressed, and recommends that the Commission, working closely with the FAA, needs to focus on, and exhaustively review, these safety-related concerns.<sup>248</sup> Garmin also contends that any grant of Ligado's applications should be preceded by explicit FAA determination and acknowledgement that operation of the proposed network is compatible with certified aviation devices.<sup>249</sup>

70. In its reply and further reply comments, Ligado reiterates that its amended operational parameters are sufficient to protect certified aviation equipment. Ligado provides several arguments in support of its proposal to adopt a 250-foot lateral limit for base station antennas in the Lower Downlink Band. First, it notes that FAA regulations provide that aircraft generally may not be operated closer than 500 feet to any person, vessel, vehicle, or structure except in limited circumstances,<sup>250</sup> and that operations within 500 feet of an object require flight by visual reference.<sup>251</sup> Therefore, Ligado contends that any potential degradation of GPS signals within 250 feet of a tower would not present a safety of flight issue.<sup>252</sup> Second, Ligado notes that FAA regulations require that pilots in command of most helicopter operations ensure ample vertical clearance to terrain and obstacles.<sup>253</sup> Ligado reiterated its commitment to work with other stakeholders to develop additional reporting procedures, beyond the requirements in the

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<sup>244</sup> See Letter from Mike Stanberry, President, Jim Arthur, Director of Operations, Metro Aviation, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109; RM-11681; IBFS File Nos. SES-MOD-20151231-00981; SAT-MOD-20151231-00090; SAT-MOD-20151231-00091, at 1-3 (filed July 9, 2018) (concluding that Ligado's proposal to protect certified aviation GPS receivers at all locations beyond a 250-foot cylinder around an antenna "is safe, reasonable, and strongly in the interests of aviation and aviation safety") (Metro July 9, 2018 *Ex Parte*).

<sup>245</sup> *Id.* at 1, 3.

<sup>246</sup> GPS/SATCOM Coalition July 18, 2018 *Ex Parte* at 1-5.

<sup>247</sup> Garmin July 9, 2018 Comments at 4-5.

<sup>248</sup> *Id.* at 8.

<sup>249</sup> *Id.* at 9.

<sup>250</sup> Ligado July 18, 2018 Reply at 6 (citing 14 C.F.R. § 91.119).

<sup>251</sup> *Id.*

<sup>252</sup> *Id.*

<sup>253</sup> *Id.* at 6-7.

FCC's Part 17 rules and the FAA's Notice of Proposed Construction or Alteration, to disseminate information necessary to protect aviation safety.<sup>254</sup>

71. *Decision.* We accept the FAA's standards-based analyses relating to certified aviation devices and condition Ligado's ATC operations accordingly.<sup>255</sup> The FAA is the expert agency with a critical interest in ensuring the reliability of certified aviation GPS devices. International and domestic standards for certified aviation devices are established and have informed FAA's analyses and conclusions that a lower downlink EIRP in the range of 9.8-13 dBW in the 1526-1536 MHz band is tolerable. Therefore, to be consistent with the finding in the FAA's certified aviation device analysis, we find it appropriate to apply the following conditions<sup>256</sup> on Ligado to protect certified aviation receivers, including: (1) base station EIRP will be limited to 9.8 dBW (10 W) with a +/- 45 degree cross-polarized base station antenna; (2) no Ligado base station antenna in this downlink band may operate at any location less than 250 feet laterally or less than 30 feet below an obstacle clearance surface established by the FAA, with a minimum inter-station separation distance of 433 meters (1420.6 feet) in a hexagonal grid; (3) Ligado must comply with specified reporting requirements to the Commission and FAA, and with other notification and monitoring obligations;<sup>257</sup> and (4) handset EIRP above 1626.5 MHz will be limited to -7 dBW.

72. We recognize that the FAA came to these conclusions based on the most restrictive scenarios involving helicopter flight near Ligado's base stations. We further recognize the FAA has not completed its evaluation on certified aviation receivers with respect to unmanned aircraft systems (UAS) using certified aviation devices. The form factor (size and weight) as well as power requirements for certified aviation devices may not be conducive to small UAS (less than 55 lbs.). Added weight takes away from payload capacity and if more power is diverted to accommodate the added weight, mission life would be reduced due to greater battery consumption. A more likely scenario would be that small UAS will use less expensive, smaller form factor, lighter weight non-certified devices. If certified aviation devices are used on larger UAS, it is reasonable to expect those UAS would respect the same obstacle clearance surfaces identified by FAA for manned aircraft (i.e., they would be protected from the 9.8 dBW and 250-foot setback conditions on Ligado's base stations). Moreover, as discussed below, the FAA and the aviation community will have access to the locations of Ligado base stations which will assist the FAA and aviation community when considering waivers to FAA UAS regulations to enable the use of certified aviation devices on UAS to perform maneuvers such as tower inspections that might involve closer proximity to Ligado's base stations.

#### **b. Non-certified GPS receivers**

73. In this section, we discuss the other GPS receivers (and GNSS receivers approved for operations in the United States<sup>258</sup>), i.e., those other than certified aviation receivers discussed above. In this discussion, we further consider the co-existence agreements that Ligado has reached with several major GPS device manufacturers, all reached before Ligado submitted its 2018 amendment. We also discuss the testing conducted in the RAA Reports and the NASCTN Report and what they say about the

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<sup>254</sup> Ligado July 18, 2018 Reply at 10-11. Ligado states that it specifically asked ASRI to identify appropriate reporting requirements and to help create and manage a database to ensure the dissemination of information relevant to protecting aviation safety. *Id.* at 11 & n.22.

<sup>255</sup> See DOT ABC Report at 152-53.

<sup>256</sup> See *infra* section H, Conditions for ATC Authority.

<sup>257</sup> See *infra* section III.H.7.

<sup>258</sup> As discussed below, we also address concerns regarding harmful interference to adjacent band Galileo GNSS operations, which the Commission has recently approved with respect to operations in the United States. Only Galileo GNSS device operations have been approved in the United States. See *infra* para 85.



potential for harmful interference to these types of GPS devices. Ligado contends that the co-existence agreements and the RAA Reports show that the harmful interference concerns related to Ligado's proposed operations can be addressed and resolved. Ligado asserts that the RAA Reports show that cellular and general navigation/location GPS devices will continue to function properly if Ligado operates its proposed network consistent with its agreements, that high-precision devices can be designed to co-exist with Ligado's network, and that in some cases for high-precision receivers, retrofitting or replacement may be necessary prior to Ligado's commencement of operations.<sup>259</sup> Ligado also contends that the NASCTN Report showed no impact on the positioning and timing of many GPS devices' receivers when exposed to LTE signals at significantly higher power than proposed by Ligado,<sup>260</sup> and Ligado asserts that the results also demonstrate that simple antenna change can eliminate any impact Ligado's proposal might have on high-precision receivers.<sup>261</sup>

74. *Ligado's co-existence agreements with major GPS device manufacturers.* As we discussed in section III.B above, beginning in 2015 and continuing through 2018, Ligado has reached co-existence agreements with several major GPS device manufacturers. Taken together, these companies have been and continue to be involved in the development of a significant number of the GPS devices and GPS-enabled products available for use—including general location and navigation (where both Garmin and Trimble are major manufacturers), general non-certified aviation (where Garmin is a major manufacturer) high-precision devices (where Garmin, Trimble, Deere, NovAtel, Topcon, and Leica are major manufacturers), and timing (where Trimble is a major manufacturer)—that are used in the United States and throughout the world. We note some of these manufacturers also are major suppliers of GPS-enabled devices to the U.S. Government.<sup>262</sup> As discussed above, they also are GPS/GNSS device manufacturers.<sup>263</sup>

75. *RAA Reports.* As discussed above, unlike the case for certified aviation devices, there are no performance-based standards for non-certified GPS devices. Absent international or domestic performance-based standards for these receivers, we rely on technical information and testing data related to their performance. The performance metrics such as 2D and 3D position accuracy provide an understanding of the functioning of a GPS device. The FCC definition of harmful interference in this context requires that we evaluate whether the modified Ligado ATC network, as amended, would endanger, seriously degrade, or repeatedly interrupt the reception of RNSS signals and cause errors in the GPS receiver's 2D or 3D position accuracy.

76. The 2016 RAA Reports involved testing to assess the potential for interference to non-certified GPS receivers from downlink and uplink channels, of the proposed Ligado ATC network as set forth in Ligado's 2015 license modification applications.<sup>264</sup> These tests were performed on 27 GPS receivers falling within the cellular, general location/navigation, including general aviation (i.e. non-certified GPS device used for aviation), and high-precision device categories. Data were collected on the 2D position error for all non-certified GPS category receivers (except for high-precision receivers where data were collected on the 3D position error) while transmitting an LTE signal on the 10 MHz downlink

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<sup>259</sup> Ligado June 5, 2017 *Ex Parte*, Attach., "Commission Action Can Unlock 40 Megahertz of Mid-Band Spectrum," Appx. A at 17.

<sup>260</sup> Ligado Feb. 24, 2017 *Ex Parte* at 2 (citing NASCTN Report at 128, 191).

<sup>261</sup> *Id.*

<sup>262</sup> See generally *supra* section III.B.

<sup>263</sup> See *supra* para. 27.

<sup>264</sup> As noted above, Ligado submitted an RAA report in May of 2016, and supplemented it in June 2016. In our references below, we provide specific cites to these reports. While we may only cite one report for the particular findings, both reports were based on the same testing, and each often could be cited for the particular findings.

channel (1526-1536 MHz) and two uplink channels (1627.5-1637.5 MHz, 1646.5-1656.5 MHz).<sup>265</sup> The RAA Reports approached interference testing by examining the impact of ATC emissions on the position error of each of the GPS receivers individually in the test suite. The test first established an average baseline position accuracy without the presence of the LTE signal. It then introduced the LTE channels (one at a time) to the receiver and increased the power level up to and beyond the power levels that would be expected to be encountered by a GPS receiver in the coverage area of Ligado's ATC base stations. It then compared the results to the GPS-reported position for the baseline condition.<sup>266</sup>

77. Several different methods to simulate the GPS signals were used in the testing based on the assumed use cases of the receiver under test.<sup>267</sup> A GPS simulator was used within a calibrated anechoic chamber. To simulate an "Open Sky" scenario, the power level was set at -130 dBm for all GPS satellites that were considered being within view of the receiver under test.<sup>268</sup> This level is 1.5 dB below the minimum guaranteed (end-of-satellite-life) level. This was intended to address scenarios where a GPS receiver has a clear view of the sky (i.e., no obstructions from foliage, buildings, or other structures). "Impaired GPS Signal" tests were also performed using simulated GPS satellites set to a power level of -142 dBm, which is 13.5 dB below the GPS specified minimum guaranteed level and was intended to represent scenarios where obstructions exist between a GPS satellite and receiver (e.g., urban canyons).<sup>269</sup> Both of these GPS simulation conditions were used in performing tests on static (GPS position is fixed) and dynamic (GPS receiver is in motion) scenarios. Furthermore, "Live Sky" tests were set up with a rooftop GPS receive antenna to capture actual (live) signals from GPS satellites. These were used to test high-precision receivers that required access to an augmentation signal in the MSS frequency band that could not be easily emulated by the simulator.<sup>270</sup>

78. The RAA testing also simulated Ligado's modified ATC downlink and uplink LTE transmissions and radiated power levels in the three frequency bands proposed by Ligado.<sup>271</sup> The power was increased from a very low level (-80 dBm) up to a level of -10 dBm, which was the maximum that could be produced by the simulator.<sup>272</sup> The LTE signal was comprised of fully allocated resource blocks for both the downlink and uplink channels. A white noise generator was used to simulate unwanted emissions falling within the RNSS allocation in which GPS operates, at levels equivalent to the Ligado proposal, and were kept constant as the fundamental LTE emission in the adjacent spectrum was stepped up to the maximum level.<sup>273</sup>

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<sup>265</sup> The RAA Reports also included testing on downlink channel 1670-1680 MHz, which is not relevant to our consideration of Ligado's modification applications. Even though use of the 1670-1680 MHz band is not before us here, some have expressed their concerns about the possibility that Ligado might operate in that band. See Letter from AccuWeather, Inc., *et al.*, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 12-340, 11-109, *et al.* (filed Apr. 16, 2020) (Hydrometeorological Apr. 16, 2020 *Ex Parte*); Letter from Steven A. Root, President, American Weather and Climate Industry Assoc., to The Hon. Ajit Pai, Chairman, FCC, IB Docket Nos. 12-340 and 11-109, *et al.* (filed Apr. 17, 2020).

<sup>266</sup> June 2016 RAA Report at 6-7.

<sup>267</sup> *Id.* at 10.

<sup>268</sup> *Id.* at 11.

<sup>269</sup> *Id.*

<sup>270</sup> *Id.* at 11.

<sup>271</sup> *Id.* at 12.

<sup>272</sup> *Id.*

<sup>273</sup> *Id.*

79. The RAA testing found “no impact”<sup>274</sup> to the three cellular devices in the presence of both the downlink and uplink channels of the modified ATC network.<sup>275</sup> 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.<sup>276</sup> 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.<sup>277</sup> 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.<sup>278</sup> 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 (32 dBW). The 3D position accuracy of the receiver was impacted at various received power levels ranging between -24 dBm and -55 dBm.<sup>279</sup> 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.<sup>280</sup> Upon retesting those high-precision devices with a more spectrally efficient antenna, they showed no impact.<sup>281</sup> 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

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<sup>274</sup> “No impact,” as used in the RAA Report, means that, with the LTE powers corresponding to the transmit power levels under the Ligado GPS proposal, there was no impact on the device performance compared to those KPI measurements with GPS alone. *See, e.g.*, June 2016 RAA Report at 38 (“no impact” on high-precision devices), 39 (“no impact” on cellular devices).

<sup>275</sup> *See id.* at 16-17 (Summary of Results).

<sup>276</sup> *See id.* at 16 (Summary of Results) and Appx. D at 35-37, §§ 8.1-8.5.

<sup>277</sup> *See id.* at 16 (Summary of Results) and Appx. D at 36, § 8.2, Tbl. 7 (concerning the Garmin eTrex device and its operation on the 1627.5-1637.5 MHz uplink). The RAA Report states that it “was observed only when the device was in motion, was receiving impaired GPS signals, and when LTE signal at the GPS device was above -30 dBm, an event that will occur with extremely low probability.” *Id.* at 16.

<sup>278</sup> *Id.*, Appx. D at 38-39, §§ 8.6-8.8.

<sup>279</sup> *Id.*, Appx. D at 38-39, §§ 8.6-8.8 Table 11: Test Performance – High Precision Devices with Various Antennae; Table 12: Test Performance – High Precision Devices, Open Sky Static; Table 13: Test Performance – High Precision Devices, Live Sky.

<sup>280</sup> *Id.*, Appx. D at 38-39, § 8.6 Table 11: Test Performance – High Precision Devices, Open Sky with Various Antennae; § 8.8 Table 13: Test Performance – High Precision Devices, Live Sky.

<sup>281</sup> *Id.*

receiver was not retested with a filtered antenna (presumably because it used a stock antenna that could not be changed).<sup>282</sup>

81. *NASCTN Report.* The NASCTN Report also collected and recorded GPS receiver output data over a range of LTE adjacent band power levels for general location/navigation, timing, and high-precision receivers. Similar to the RAA testing, general location/navigation showed the least susceptibility to adjacent band LTE signals, while high-precision showed the most susceptibility.<sup>283</sup> 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.<sup>284</sup>

82. *Comments.* Several commenters support Ligado's licensed modification applications, as amended. Spectrum Financial Partners and Roberson and Associates agree with Ligado that technical analysis in the record supports granting Ligado's amended license modifications.<sup>285</sup> In its comment, RAA states that the 2016 RAA testing shows that reducing the downlink to power levels of 9.8 dBW would mean that some of the high-precision GPS receivers that had been affected at 32 dBW levels would no longer be affected.<sup>286</sup> 3C Systems Company reviewed the RAA and NASCTN Reports and asserts that Ligado's proposed network would not result in harmful interference to non-certified GPS devices.<sup>287</sup> Several others, including the Competitive Carriers Association, Public Knowledge and X-Lab, the Free State Foundation, Apium Swarm Robotics, the Information Technology & Innovation Foundation, and Teleworld Solutions, favor making more spectrum available for new innovative terrestrially-based services, including IoT.<sup>288</sup>

83. We also received comments in opposition to Ligado's amended proposal on the grounds that the amended operating parameters would not protect non-certified GPS receivers. GPS/SATCOM Coalition also opposes Ligado's proposal contending harm to GPS receivers, pointing to the NPEF Gap

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<sup>282</sup> June 2016 RAA Report, Appx. D at 38-39, §§ 8.6-8.8. The receiver that was not retested was a NovAtel receiver. *Id.*

<sup>283</sup> See, e.g., NASCTN Report at 127 (Fig. 6.6), 147 (Fig. 6.26).

<sup>284</sup> See *id.* at 171 (Fig. 6.50, DUT 11 and 12), 146 (Fig. 6.25, DUT 9).

<sup>285</sup> Spectrum Financial Partners, LLC July 9, 2018 Comments at 1-5; Roberson and Associates July 9, 2018 Comments at 1-3.

<sup>286</sup> Roberson and Associates July 9, 2018 Comments at 3. The 3D position accuracy of some GPS receivers in the RAA testing was impacted at various received power levels ranging between -24 dBm and -55 dBm. See note 279, *supra*. Roberson states that applying the conclusions from the RAA Report that assumed a 32 dBW base station power levels to analyze Ligado's new 9.8 dBW power levels (greater than two orders of magnitude) results in a new conclusion that the likelihood of Ligado's downlink operations causing harmful interference to any non-high precision devices is "extremely rare, with a probability effectively of zero," and that the high-precision devices that it tested that would have been susceptible to interference from 32 dBW stations would no longer be susceptible at 9.8 dBW even without a replacement filtered antenna. Roberson and Associates July 9, 2018 Comments at 2. Roberson states that by reducing the base-station power from 32 dBW to 9.8 dBW – a reduction of over 22 dB – the 99<sup>th</sup> percentile received power level is shifted to less than -42 dBm (less than 1/10<sup>th</sup> of a microwatt). Roberson further states that, considering that the RAA Report shows that high-precision GPS devices with filtered antennas have been shown to co-exist with 32 dBW base transmitters, reducing the base transmitters to 9.8 dBW further reduces the need for additional filtering). *Id.*

<sup>287</sup> 3C Systems Company July 6, 2018 Comments at 1-3.

<sup>288</sup> See Competitive Carriers Association July 19, 2018 Comments at 1-2; Public Knowledge and X-Lab July 9, 2018 Comments at 1-3; Apium Swarm Robotics July 9, 2018 Comments at 1; Information Technology & Innovation Foundation July 9, 2018 Comments at 1-3; Teleworld Solutions July 6, 2018 Comments at 1-2; American Tower July 16, 2018 Comments at 1-2; Wireless Infrastructure Association July 18, 2018 Comments at 1; Free State Foundation July 19, 2018 Reply at 1-3; Maritime Advanced Research, Inc. July 25, 2018 Reply at 1.

Analysis.<sup>289</sup> As noted above, although Garmin, Trimble, and Deere each have entered into co-existence agreements with Ligado, Garmin and Deere state that this should not be taken to mean that all GPS devices will be protected from interference from Ligado's proposed operations.<sup>290</sup> Trimble also contends that the performance metrics used by the RAA and the NASCTN testing do not provide a reliable basis for determining harmful interference.<sup>291</sup> ASRI contends that, contrary to Ligado's approach, the DOT ABC Report states a power level of 9.8 dBW may "cause interference with, or degradation to, most other categories of GPS receivers including those used for General Aviation and drones."<sup>292</sup> Boeing also submits that questions regarding potential interference from Ligado's proposed operations to GPS receivers used in general aviation and drones must be resolved.<sup>293</sup> In addition, the Alliance of Automobile Manufacturers expresses concern that Ligado's proposed operations could pose a significant risk of harmful interference to current and future transportation safety applications that use GPS signals.<sup>294</sup> More recently, federal agencies, including DOD, also have expressed concerns regarding the potential impacts of Ligado's proposed system on GPS operations.<sup>295</sup>

84. *Decision.* In evaluating the record before us relating to non-certified GPS devices, we consider both the co-existence agreements with major GPS device manufacturers (including conditions contained in them regarding Ligado's roll out of its network) and the receiver performance-based testing results before us. Together, they help us evaluate the potential for harmful interference and address the concerns that have been raised in this proceeding and whether they are addressed for purposes of authorizing Ligado's modified operations.

85. We find that co-existence agreements with several of the major GPS device manufacturers are critical to our considerations. As discussed above, these manufacturers have long been involved in the development and distribution of the non-certified GPS-enable devices that we have been examining since the beginning of this proceeding. They are major manufacturers of general/location navigation (including general non-certified aviation), high-precision, and timing receivers used in the United States (including by the U.S. government) and throughout the world. These manufacturers, respectively, best know their various receivers and how they are designed and perform—including the many devices previously produced and distributed in the marketplace and those being developed now and for the future. Together, these agreements take into account representative GPS devices and categories of those devices in the market today. Each manufacturer also has been a participant in this proceeding, and their devices have been tested in the different studies and reports submitted in this proceeding since 2011 including in the RAA and NASCTN Reports. They all had, at some time prior to entering into co-existence agreements with Ligado, expressed significant concerns about Ligado's ATC network and had completely opposed authorizing Ligado's ATC operations. They each have abandoned their earlier

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<sup>289</sup> GPS/SATCOM Coalition July 18, 2018 *Ex Parte* at 1-5.

<sup>290</sup> Garmin July 26, 2018 Reply at 2-3 and n.4; Deere July 9, 2018 Comments at 7. Garmin also notes that not all Garmin consumer devices are compatible with Ligado's proposed operations. Garmin July 26, 2018 Reply at 2.

<sup>291</sup> Trimble July 9, 2018 Comments at 3.

<sup>292</sup> ASRI July 24, 2018 Reply at 10 (quoting DOT ABC Report at 158); *see also* Resilient Navigation and Timing Foundation Nov. 14, 2019 *Ex Parte* at 1.

<sup>293</sup> Boeing Company July 9, 2018 Comments at 2-3.

<sup>294</sup> Letter from Jonathan Weinberger, Vice President, Technology and Innovation Policy, Alliance of Automobile Manufacturers, Inc., to the Hon. Ajit Pai, Chairman, FCC, at 1-2 (filed Oct. 23, 2018).

<sup>295</sup> NTIA Dec. 6, 2019 Letter (including enclosed letters from the PNT EXCOM and DOD); NTIA Apr. 10, 2020 Letter (including enclosures from DOD and the U.S. Air Force); *see also* Hydrometeorological Apr. 16, 2020 *Ex Parte* at 2-3 (expressing continued concerns about Ligado's proposal and referencing concerns raised in NTIA's April 2020 and December 2019 letters); Coalition of Aviation, Satellite Communications, and Weather Information Users Apr. 15, 2020 *Ex Parte* at 1-2 (same).

oppositions and have reached agreement with respect to Ligado's 2015 license modification applications. As discussed above, in conjunction with the various conditions in their respective agreements with Ligado, they have each determined that co-existence of their many devices with Ligado's revised network proposal can be achieved and that previously raised interference concerns have been addressed.

86. As for evaluation of the recent additional testing of these non-certified GPS devices, we rely on technical information provided in the record that demonstrates whether the RNSS functions of non-certified GPS receivers would be endangered, seriously degraded or repeatedly interrupted in the presence of transmissions in the spectrum adjacent to the RNSS allocations. To the extent that certain of the technical information and arguments in the record assess the potential interference issues using a 1dB metric, we do not rely on that information for the reasons discussed above.<sup>296</sup> Instead, we rely on the technical data and analysis in the RAA testing and the results of the NASCTN testing. Although the number of receivers tested is limited, we nonetheless find that the testing approaches incorporate sound engineering methodologies and practices, and lacking opposition from GPS receiver manufacturers about whether the devices tested effectively cover receiver market segments, we draw the conclusion that they are representative of the various types of deployed GPS receivers.

87. Our decision is also informed by drive test data of an operating LTE network that RAA testing uses to verify its approach to statistically quantify the power levels that would be present at a receiver at discrete separation distances relative to its modified ATC base station transmitters. Specifically, the RAA testing uses actual measured LTE received power level data within a base station cell that Ligado collected from drive tests performed within the Washington, D.C. metropolitan area using established LTE commercial deployments.<sup>297</sup> The RAA Reports claimed this to be a superior approach as compared to the use of the free-space propagation model.<sup>298</sup> We note that such an approach will likely account for LTE power variabilities due to resource block allotments and automatic power control techniques that were not accounted for in the simulated signals used in the RAA or NASCTN Reports. That is, the behavior of the GPS receiver was subjected to the most interfering LTE signal where all resource blocks were allotted and the power level was at its maximum (which would only be the case to serve one LTE device when it is at the edge of the cell coverage area). The RAA Report concluded that this approach "reveals that a GPS receiver will experience LTE levels less than -20 dBm more than 99% of the time in all environments, except for the [r]ural case, where the value is nearly 99%, at 98.54%."<sup>299</sup> The RAA testing then performed subsequent analyses to compare the measured GPS receiver susceptibility threshold levels to the maximum LTE level of -20 dBm. The RAA testing compared that value to the measured interference susceptibility power levels of the GPS devices tested to determine whether the received LTE power level of -20 dBm would be high enough to result in a negative impact (i.e., degradation to accuracy) to the GPS device. Specifically, if the susceptibility of the GPS receivers was found to be less than -20 dBm based on the measurement results, where 2D or 3D accuracy was assumed as the metric, then a finding of "no impact" was declared.<sup>300</sup>

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<sup>296</sup> See *supra* paras. 47-59.

<sup>297</sup> June 2016 RAA Report, Appx. C at 3, § 7.1.

<sup>298</sup> *Id.*, Appx. C at 4-7, § 7.3.1.1.

<sup>299</sup> *Id.*, Appx. C at 8-9, § 7.3.1.2. In comments filed after Ligado had submitted its modified applications in 2018, Roberson states that for a 32 dBW transmitter using Monte Carlo simulations, the aggregate received power level would be less than -23.7 dBm in 99 percent of locations. The RAA analysis used a higher and therefore more conservative value of -20 dBm to indicate the 99<sup>th</sup> percentile (i.e., 99 percent of the locations have power less than -20 dBm). Roberson further states that reducing the base-station power to Ligado's proposed level of 9.8 dBW, – a reduction of over 22 dB – would shift the 99<sup>th</sup> percentile received power level to less than -42 dBm, or less than 1/10<sup>th</sup> of a microwatt. Roberson and Associates July 9, 2018 Comments at 3.

<sup>300</sup> *Id.*, Appx. D at 35-39, §§8.1 through 8.10.

88. We conclude that there is little or no potential for harmful interference from Ligado's modified ATC base station or handset operations to the hundreds of millions of cellular devices in the marketplace. All of the testing has shown that cellular devices are least susceptible among all of the various categories of GPS devices. We further conclude that Ligado's modified ATC network should not cause harmful interference to general location and navigation devices (including general non-certified aviation receivers). The RAA Report identified one general location/navigation device that was affected (and only by Ligado's uplink handset operations, not the downlink operations) when that device was receiving an "impaired" GPS signal while in motion, but concluded that this would be an event that would occur with extremely low probability.<sup>301</sup> We observe that this particular device was manufactured by one of the companies with whom Ligado has reached a co-existence agreement, and which does not object to Ligado's proposed operations in the uplink bands.<sup>302</sup> Moreover, RAA testing found no impact to the general aviation receiver tested. We observe further that if the general non-certified aviation device is used on a drone, then it could operate within about 50 feet of the base station where the power level at the receiver is at the -20 dBm level (assuming a transmitter power of 9.8 dBW and free space path loss in the main beam of the antenna).

89. We also find that high-precision receivers should be able to co-exist with Ligado's modified ATC network operations in the adjacent spectrum. As discussed above, the variability in interference susceptibility is most pronounced for high-precision receivers, and both the RAA and NASCTN Reports showed potential impact to them.<sup>303</sup> However, the testing also revealed that high-precision receivers can be made immune to harmful interference by using filtered antennas that are more spectrally efficient even though they include relatively wide RF filters associated with these types of GPS devices.<sup>304</sup> From those reports, we note that the dual band antennas used with many of the high-precision receivers are the prominent obstacle to achieving compatibility with Ligado's downlink channel. Several of the antennas are designed to simultaneously receive GPS L1 signals (operating in the 1559-1610 RNSS allocation) and GPS L2 signals (operating in the 1215-1240 MHz RNSS allocation, separated by over 300 megahertz) which offers no rejection to Ligado's downlink transmissions in the band adjacent to the RNSS allocation where the GPS L1 signal is transmitted.<sup>305</sup> When the antenna frequency response characteristics are correlated with the test data in the RAA and NASCTN Reports, it explains the extreme variability (between 60-70 dB) observed in the receiver performance results and the positive change in re-tested receivers after a more selective antenna replaced the stock receiver antenna. We further conclude that it is technically possible and feasible to retrofit (or replace, where retrofitting is infeasible) those high-precision receivers that may experience harmful interference and that retrofitting or replacing covered receivers would remedy harmful interference. For high-precision receivers that could experience harmful interference where it is not technically possible to retrofit them with more spectrally efficient antennas, we would expect any identified potential harmful interference to be addressed as a result of the notification processes that we are requiring. These processes (described further below as one of the conditions that we are requiring<sup>306</sup>) will provide Ligado, the U.S. Government, and GPS device

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<sup>301</sup> June 2016 RAA Report at 16 and Appx. D at 36, § 8.2. This testing scenario involved a type of low probability scenario in which the GPS device was receiving a weak GPS signal, while in motion, at the same time that the LTE handset signal was transmitting high power LTE signals. *Id.* at 16.

<sup>302</sup> This particular device was manufactured by Garmin, which does not object to Ligado's uplink operations. *See id.*, Appx. D at 36, § 8.2; Garmin Agreement at 22-24, §§ 9-10.

<sup>303</sup> *See* June 2016 RAA Report, Appendices D & E at 35-41; NASCTN Report at 128, 191.

<sup>304</sup> *See supra* paras. 80-81.

<sup>305</sup> *See, e.g.*, NASCTN Report at 13, Table 2.4; NovAtel Manuals GPS-701/702-GGL Antenna at 1, <https://www.novatel.com/support/info/documents/528>.

<sup>306</sup> *See infra* paras. 144-145.

manufacturers (per their agreements with Ligado) an opportunity to identify and retrofit/replace potentially affected, covered devices in advance of Ligado commencing ATC operations. Should harmful interference occur after ATC deployment, it will be remedied by the conditions we place on Ligado's ATC operations. Finally, we note that the RAA Report showed that high-precision receivers could co-exist with Ligado's modified network when transmissions operated at power levels up to 32 dBW (with some requiring filter retrofit or replacement), and we would expect that limiting the transmissions to power levels no greater than 9.8 dBW, as we do here, will significantly reduce the need for filter replacement.<sup>307</sup>

90. Finally, our analysis of the interference concerns relating to GPS-enabled devices extends to GNSS devices operating with Galileo E1 signals pursuant to the waiver of Part 25 licensing rules the Commission granted in November 2018. As discussed in that decision, we afford operations using Galileo's E1 signals in the 1559-1610 MHz RNSS allocation the same harmful interference protection rights as those afforded non-Federal receivers operating with GPS signals in that band.<sup>308</sup> Consequently, our determinations in this proceeding regarding GPS-enabled devices address the harmful interference concerns with devices that operate using Galileo GNSS signals.

91. Overall, we find that, based on these technical studies, the co-existence agreements with major GPS device manufacturers, the substantial reduction in maximum power levels, and the several conditions that we are adopting, Ligado's modified ATC network should not cause harmful interference to non-certified GPS receivers. Our analysis should not be construed to say that there is no potential for harmful interference to any GPS device currently in operation or in the marketplace. Indeed, the RAA testing shows that there is potential for harmful interference to some devices, particularly high-precision devices. We nonetheless conclude that the advance notification and other conditions we discuss below, which build on commitments that Ligado has made with several GPS device manufacturers, will address any identified potential harmful interference to GPS before ATC network operations commence.

**c. Ligado's commitment to additional reporting, notification, and monitoring**

92. As a condition for operating in the 1526-1536 MHz band, Ligado proposed in its 2018 amendment that the Commission require it to comply with reporting, notification, and monitoring obligations.<sup>309</sup> Specifically, Ligado proposed (1) reporting its base station locations and technical operating parameters to the Commission and the FAA prior to commencing operations, (2) continuous monitoring obligations relating to each of its station's transmit power, and (3) procedures and actions for responding to credible reports of interference (maintenance of a toll-free number to report apparent incidences of interference, investigation, rectification if necessary, and notification of the Commission in such an event).<sup>310</sup>

93. In response, ASRI contends that Ligado's proposed reporting and monitoring obligations are inadequate.<sup>311</sup> It argues that by notifying only the FAA and FCC of its proposed base station locations

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<sup>307</sup> Roberson and Associates July 9, 2018 *Ex Parte* at 3 (the RAA testing shows that the high-precision receivers that it tested would have been susceptible to interference from base stations operating at 32 dBW would no longer be susceptible at 9.8 dBW even without a replacement filtered antenna; given that the testing shows that high-precision GPS devices with filtered antennas have been shown to co-exist with 32 dBW base transmitters, reducing the base transmitters to 9.8 dBW "further reduces the need for additional filtering").

<sup>308</sup> See *Waiver for Part 25 Licensing Requirements for Receive-Only Earth Stations Operating with the Galileo Radionavigation-Satellite Service*, IB Docket No. 17-16, Order, 33 FCC Rcd 11322, 11336, paras. 2, 31 (2018).

<sup>309</sup> Ligado May 31, 2018 *Ex Parte* at 2.

<sup>310</sup> Ligado May 31, 2018 *Ex Parte* and Ligado Amendment, Exhibit 1.

<sup>311</sup> ASRI July 9, 2018 Comments at 5-7.



and technical operating parameters, and doing so confidentially, Ligado would create unnecessary and safety-threatening obstacles to aviation operators to obtain this important information.<sup>312</sup> To obtain this information, ASRI contends, operators would have to proactively and continuously search FAA and FCC public notices to see if Ligado has made such a filing and then would have to request access through the FCC's confidentiality procedures before receiving notice of new and modified stations that could impact the environment in which certified GPS receivers operate.<sup>313</sup> ASRI also contends that Ligado's proposal does not consider the implications for interference reporting and enforcement activities.<sup>314</sup>

94. Ligado responds by reiterating its commitment to satisfy the reporting procedures that the Commission deems appropriate, and its willingness to work with stakeholders, including ASRI, to develop further the reporting procedures that Ligado has proposed.<sup>315</sup> It notes that its proposed reporting obligations are not a replacement for existing Commission and FAA reporting obligations and that Ligado will adhere to all relevant tower reporting rules that apply to wireless carriers.<sup>316</sup> It states that Ligado remains willing to put this commercially sensitive information in a database that can be accessed by all stakeholders and to pay for the building and maintenance of this database by any responsible party.<sup>317</sup>

95. *Decision.* We find that the reporting and monitoring procedures proposed in Ligado's 2018 amendment, in conjunction with the "Responsiveness and Notification of Interference Complaints" section of the conditions applicable to grant of the ATC authority we adopt in section G below, will ensure that Ligado's operations do not result in harmful interference to adjacent band operations. We agree with ASRI, however, that accurate and timely information about Ligado base stations and technical operating parameters should be made more broadly available to the aviation community to help operators avoid harmful interference to their GPS systems. Therefore, we will revise Ligado's obligations to require that, in addition to reporting its base station location information and technical operating parameters to the FCC and FAA prior to commencing operations in the 1526-1536 MHz band, Ligado work with relevant stakeholders, including ASRI,<sup>318</sup> in order to create a database that will disseminate such information to the affected aviation community prior to commencing operations in this spectrum.<sup>319</sup> Ligado will be required to certify, in its reports to the FCC and FAA prior to commencing operations, that the database has been created and is operational, as set forth in section G (Conditions) below.

**d. Ligado's commitment to upgrade or replace U.S. Government devices and related further conditions**

96. In its 2018 amendment, Ligado also proposes to commit to mitigation measures to address concerns about the impact of its proposed ATC operations on U.S. Government devices, including but not limited to upgrading or replacing devices.<sup>320</sup> Ligado states that, although the overwhelming number of GPS devices will not be affected, it is aware that some federal stakeholders have concerns that some specialized devices, particularly high precision devices, may need to be repaired

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<sup>312</sup> ASRI July 9, 2018 Comments at 5-6.

<sup>313</sup> *Id.* at 6.

<sup>314</sup> *Id.* at 6-7.

<sup>315</sup> Ligado July 19, 2018 Reply at 10-11.

<sup>316</sup> *Id.*

<sup>317</sup> *Id.* at 11.

<sup>318</sup> We expect that ASRI, considering its concerns, expertise, and long-standing engagement in this proceeding, will work in good faith with Ligado in this effort.

<sup>319</sup> See *infra* section H, Conditions for ATC Authority.

<sup>320</sup> Ligado May 31, 2018 *Ex Parte* at 2.

or replaced. Ligado further states that it does not expect any federal GPS devices will experience harmful interference, and notes that this conclusion is buttressed by the co-existence agreements with the major GPS manufacturers, including the leading high-precision device makers.<sup>321</sup> 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.<sup>322</sup> Ligado identifies two exceptions to the general prohibition on federal agencies receiving equipment or services directly from a third party that Ligado argues are applicable to the potential repair or replacement of impacted U.S. Government devices. First, Ligado cites Government Accountability Office (GAO) precedent permitting the repair or in-kind replacement of property that has been damaged by a third party.<sup>323</sup> Second, Ligado argues that repair or in-kind replacement of devices would be a permissible non-gratuitous conveyance as consideration for approval of Ligado's modified application.<sup>324</sup> Except for general concerns raised by the Resilient Navigation and Timing Foundation,<sup>325</sup> no party specifically addressed Ligado's proposed mitigation commitment in the record.

97. In filings in 2019, however, NTIA notes federal agencies' concerns about potential impacts of Ligado's proposed system to the agencies' missions and national security,<sup>326</sup> while DOD expresses concerns about too many "unknowns" and risks to federal operations, including a potential significant negative impact on military operations.<sup>327</sup> More recently, in April 2020, NTIA submitted to the Commission a February 2020 Air Force memorandum to NTIA providing additional information on DOD's and other federal agencies' concerns.<sup>328</sup> The Air Force memorandum contends that the extensive testing and analysis conducted since 2011 by DOD, the NPEF, DOT, and the Air Force, has shown that Ligado's proposed license modification could implicate "a vast number of systems" and could threaten disruption of GPS, which would cause unacceptable operational impacts to the warfighter and adversely affect the military potential of GPS by negatively impacting GPS receivers.<sup>329</sup> It asserts that Ligado's proposal to replace government receivers is a "tacit admission" that there would be interference.<sup>330</sup> Assuming such interference occurs, the memorandum provides information on the national defense mission categories that it believes would be negatively affected,<sup>331</sup> the cost and resource implications of identifying and repairing or replacing potentially adversely affected receivers supporting defense

<sup>321</sup> Ligado July 9, 2018 Comments at 14.

<sup>322</sup> *Id.* at 14-15.

<sup>323</sup> *Id.* at 15-16 (citing *Maritime Administration – Disposition of Funds Recovered from Private Party for Damage to Gov't Building*, B-287738, 2002 WL 1554364, at \*3 (Comp. Gen. May 16, 2002)).

<sup>324</sup> *Id.* at 16-17 (citing *LCPtracker, Inc.; eMar, Inc.*, B-410752.3 et al, 2015 CPD para. 279 at 1 (2015); *Gen. Services Administration: Real Estate Brokers' Commissions*, B-291947, 2003 WL 21947188 (2003)).

<sup>325</sup> See Resilient Navigation and Timing Foundation Nov. 14, 2019 *Ex Parte* at 2-3 (claiming that Ligado's offer to compensate the government for harm to its users suffers from several deficiencies).

<sup>326</sup> NTIA Dec. 6, 2019 Letter at 2.

<sup>327</sup> DOD Nov. 18, 2019 Letter at 1; DOD June 7, 2019 Letter.

<sup>328</sup> NTIA Apr. 1, 2020 Letter; Air Force Feb. 2020 Memorandum.

<sup>329</sup> Air Force Feb. 2020 Memorandum at 1. The Air Force states that it is submitting this supplemental information to NTIA in the exercise of DOD's statutory duties under 10 U.S.C. § 2281, and as the Executive Agent for the Global Positioning System and in its role as a member of the NTIA Interdepartmental Radio Advisory Committee (IRAC). *Id.* at 1.

<sup>330</sup> *Id.* at 2.

<sup>331</sup> The memorandum cites as examples precision weapons, communications networks and synchronization, command and control, civil engineering and surveillance applications. *Id.* at 3.

missions, and the time, disruption, and programmatic impact that would be required to identify and repair or replace these receivers. According to the Air Force memorandum, the mitigation measures that Ligado has proposed are “impractical and un-executable in that they would shift the risk of interference to, and place enormous burdens on, agencies and other GPS users to monitor and report the interference.”<sup>332</sup> The Air Force states that it would be “practically impossible” for DOD to identify and repair or replace all of the potentially affected legacy receivers, including high-precision military receivers that may be vulnerable.<sup>333</sup> The Air Force memorandum contends that Ligado does not know the magnitude of the problem or the costs and operational impacts relating to military receivers given the classified nature and number of the military platforms potentially affected<sup>334</sup> and that that number could be quite large and would cause significant operational impact.<sup>335</sup> It states that modification or replacement of GPS receivers within DOD has historically taken approximately a decade,<sup>336</sup> and that the time required to modify or replace affected receivers could jeopardize DOD forces and warfighting capabilities.<sup>337</sup> In addition, the Air Force states that the mitigation proposal for U.S. Government receivers, “even if technically feasible,” only covers those receivers owned by the government and “would leave many high-value federal uses of civil GPS receivers not owned by the government, such as high-precision receivers, vulnerable to interference.”<sup>338</sup>

98. In response, Ligado contends that NTIA’s filing and enclosed letters raise no new evidence, arguments, or claims, that it is based on “unsupported and overblown” of threats to the military use of GPS,<sup>339</sup> and that the Air Force memorandum relies on “irrelevant and misleading data.”<sup>340</sup> Ligado asserts that the Air Force memorandum ignores “what is perhaps the most critical and basic fact” that the proposal before the Commission is Ligado’s 2018 amended applications in which its operations would be limited to 9.8 dBW, not the earlier proposed operating level of 32 dBW.<sup>341</sup> Ligado states that under a maximum power level of 9.8 dBW, almost all of the high-precision devices tested in the 2016 RAA Reports that were affected at 32 dBW are not affected, and that the affected devices were manufactured by GPS device manufacturers who have co-existence agreements with Ligado and do not object to Ligado’s proposed operations.<sup>342</sup> Ligado further asserts that extensive testing and the co-existence agreements with major GPS device manufacturers, as set forth in the record, establish that the operations

<sup>332</sup> Air Force Feb. 2020 Memorandum at 1-2.

<sup>333</sup> The memorandum notes that GPS is widely and heavily integrated throughout DOD operations and applications and embedded into DOD testing, training, exercise, and operations. It further states that these devices are not simple “plug-and-play” and would require significant time and resources to effect software modifications, trial and testing, and validation. *Id.* at 3-4. The memorandum expresses specific concern about legacy military receivers, asserting that modernized GPS receivers cannot replace all military GPS currently in use, noting in particular that high-precision military receivers may be vulnerable.

<sup>334</sup> *Id.* at 4.

<sup>335</sup> *Id.* at 4-5 (stating that almost every GPS receiver throughout the DOD joint force potentially could be affected, as well as every weapons system or platform in the DOD inventory).

<sup>336</sup> *Id.* at 5 (stating that this was due to the receiver numbers, complications with how receivers are integrated into thousands of platforms and systems, and issues around depot and scheduling and global operations).

<sup>337</sup> *Id.* at 5.

<sup>338</sup> *Id.* at 2. *See id.* at 3-4 (noting that DOD makes use of many civil GPS receivers in non-combat environments, such as surveying, flight training, training, exercises, other national security events, and scientific applications).

<sup>339</sup> Ligado Apr. 12, 2020 *Ex Parte* at 1.

<sup>340</sup> *Id.* at 2.

<sup>341</sup> *Id.* at 2.

<sup>342</sup> *Id.* at 2-4.

of GPS devices “will not be compromised,” and that the Air Force memorandum does not provide any new technical evidence in the record regarding potential harmful interference to GPS devices.<sup>343</sup> Ligado also rejects the Air Force’s contention that many high value uses of civil GPS devices not owned by the government would be vulnerable to interference, pointing to its co-existence agreements with GPS manufacturers.<sup>344</sup> In addition, Ligado contends that claims of threats to military use are unsupported insofar as they inappropriately rely on a 1 dB metric.<sup>345</sup>

99. *Decision.* We agree that it is critical to ensure that U.S. Government devices do not experience harmful interference. Therefore, notwithstanding our conclusion with regard to the risk of potential harmful interference at 9.8 dBW, we adopt several requirements, including processes and conditions, to ensure that Ligado takes all necessary mitigation measures to prevent or remediate any potential harmful interference to U.S. Government devices, including devices used by the military, that are identified both pre- and post-deployment of Ligado’s network. The requirements that we are adopting are necessary and in the public interest and consistent with the Commission’s goal of ensuring successful co-existence between Ligado’s operations, GPS services, and other services on adjacent bands. As a fiscal law matter, GAO has long recognized that it is permissible for a party that damages government property (or its insurer) to replace the damaged property “in kind” or make direct payment to a repair facility for its repair or replacement.<sup>346</sup>

100. The significantly reduced power levels at which Ligado will operate (compared to its earlier proposals), along with the co-existence agreements it has entered into since 2015, significantly lower the potential for harmful interference to GPS devices, including those owned by the U.S. Government. Further, as extensively discussed in this Order, we evaluate the potential for harmful interference from Ligado’s proposed operations by relying on studies that apply performance-based metrics, and not on testing based on the use and application of a 1 dB metric that we find problematic and inappropriate. As the technical data and analyses in the 2016 RAA Reports and the 2017 NASCTN Report demonstrate, GPS receivers, including high-precision receivers, are technically capable of co-existing with Ligado’s modified network operations in the adjacent spectrum. The RAA Report showed that high-precision receivers could co-exist with Ligado’s modified network when transmissions operated at power levels up to 32 dBW (with some requiring filter retrofit or replacement).<sup>347</sup> The studies that the Air Force memorandum rely upon not only are based on use of a 1 dB metric that we have found inappropriate, but also are based on Ligado’s earlier proposal to operate at power levels up to 32 dBW instead of 9.8 dBW as proposed in Ligado’s subsequent 2018 license modification application—a 99.3% reduction in power that will significantly reduce the likelihood of any harmful interference to GPS devices. We agree with Ligado that limiting the transmissions to power levels no greater than 9.8 dBW will significantly reduce the potential for harmful interference in the first place and significantly reduce

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<sup>343</sup> Ligado Apr. 12, 2020 *Ex Parte* at 4-5.

<sup>344</sup> *Id.* at 2-4.

<sup>345</sup> *Id.* at 5-6.

<sup>346</sup> See *Maritime Administration—Disposition of Funds Recovered from Private Party for Damage to Gov’t Bldg.*, B-287738, 2002 WL 1554364; *Bureau of Alcohol, Tobacco, and Firearms—Augmentation of Appropriations—Replacement of Autos by Negligent Third Parties*, 67 Comp. Gen. 510, B-226004, (1988); B-87636 (Aug. 4, 1949).

<sup>347</sup> Ligado Apr. 12, 2020 *Ex Parte* at 2-3; see also Roberson and Associates July 9, 2018 *Ex Parte* at 3 (the RAA testing shows that the high-precision receivers that it tested would have been susceptible to interference from base stations operating at 32 dBW would no longer be susceptible at 9.8 dBW even without a replacement filtered antenna; given that the testing shows that high-precision GPS devices with filtered antennas have been shown to co-exist with 32 dBW base transmitters, reducing the base transmitters to 9.8 dBW “further reduces the need for additional filtering”).

the need for filter repair or replacement.<sup>348</sup> Finally, Ligado's co-existence agreements with major GPS device manufacturers, some of whom supply GPS devices to the U.S. Government and do not object to Ligado's proposed operations, substantiate that such co-existence is possible and feasible. Because of the reduced power levels of Ligado's proposed operations, which are significantly below those that raised concerns for the Air Force, we therefore do not agree with the Air Force memorandum's contention that relevant testing and analysis shows that "a vast number of systems" are implicated and that it inevitably would be too impractical or infeasible to identify and repair or replace potentially affected receivers such that we should not to move forward with authorizing Ligado's operations.<sup>349</sup>

101. We recognize, however, that there could potentially be some limited cases, particularly with respect to high-precision receivers, where repair or replacement may be required to protect legacy GPS devices from potential harmful interference. To address these concerns, we are requiring additional preventative measures to ensure that U.S. Government GPS receivers are protected under these circumstances. To this end, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's ATC operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program to repair or replace any such devices that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. We would expect the affected agency to provide information to Ligado as well, including identifying geographic areas where Ligado's proposed deployments could create risks of harmful interference to U.S. Government GPS receivers.<sup>350</sup> As part of this coordination, Ligado is required to launch a program to facilitate the exchange of information between it and the U.S. Government, including DOD and other affected agencies, within six months of the release of this Order and Authorization or no less than 30 days prior to the deployment of a downlink base station at 1526-1536 MHz under ATC authority, whichever is sooner.

102. Using the information sharing requirements we adopt here, Ligado must provide information that will assist Federal agencies in identifying potentially affected U.S. Government GPS devices, including military systems and platforms containing such devices, and expeditiously upgrade, repair or replace such devices, as necessary. We note, as Ligado has suggested, that the GPS manufacturers that have co-existence agreements with Ligado may have already repaired or replaced potentially affected GPS receivers (whether military or civil devices),<sup>351</sup> and that in any event those manufacturers that have supplied GPS devices to federal users can be helpful to Ligado in identifying particular GPS devices that still may need to be repaired or replaced if that has not already occurred. We believe that through these requirements and processes, most potentially affected GPS receivers can be identified and repaired or replaced before ATC operations commence.

103. We further acknowledge that it is possible that for a small subset of high-precision receivers it would be unreasonable to expect repair or replacement to serve as a viable option for

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<sup>348</sup> As RAA found in July 2018, reducing base-station power to Ligado's proposed level of 9.8 dBW would shift the 99th percentile received power level for GPS devices to less than -42 dBm. Roberson and Associates July 9, 2018 Comments at 3. All but two of the high-precision receivers RAA tested 2016 showed no impact under this reduced power level, and the two devices that were affected were manufactured by companies with whom Ligado has entered into co-existence agreements. Ligado Apr. 12, 2020 *Ex Parte* at 1-6.

<sup>349</sup> Air Force Feb. 2020 Memorandum at 1.

<sup>350</sup> *Id.* at 3-4.

<sup>351</sup> Ligado Apr. 12, 2020 *Ex Parte* at 3-4.

addressing potential harmful interference concerns.<sup>352</sup> As set forth in the Air Force memorandum, it may not be practical to repair or replace military GPS receivers under some circumstances, such as where the embedded nature of the receiver would make repair or replacement economically unfeasible.<sup>353</sup> If an affected agency determines, based on the base station and technical operating data made available to it, that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation, it should immediately provide Ligado with such information so it can verify that a deployment at authorized power levels would cause harmful interference. If, in such circumstances, the GPS receiver is incapable of being fully tested or replaced, we would expect Ligado and the affected government agency to negotiate an acceptable received power level over the military installation.<sup>354</sup>

104. We defer to Ligado and relevant U.S. Government agencies the format for providing the information to be exchanged pursuant to this Order, whether through the database created in coordination with ASRI and other stakeholders, or by some other means. Consistent with FCC precedent in other proceedings,<sup>355</sup> we would expect Ligado and U.S. Government agencies to work together in good faith, including with regard to negotiation to resolve any disputes, related to (1) Ligado's commitments to upgrade, repair or replace covered devices and (2) an acceptable received power level over military installations identified by U.S. government agencies. Ligado shall also make available technical experts to support the repair and replacement program.

105. Finally, we address several of the remaining assertions in the Air Force memorandum. First, we disagree that granting Ligado's 2018 license modification applications would shift the burden onto U.S. governmental agencies to monitor and report interference issues.<sup>356</sup> We are conditioning our approval of Ligado's ATC authority on Ligado's commitment to maintain network operations center procedures for 24/7 continuous monitoring of the transmit power for each of its base station sites. This, combined with the information-sharing and negotiation requirements we adopt here, places the burden primarily on Ligado, and not the affected government agencies. Second, to the extent the Air Force is concerned with potential effects to GPS receivers used in support of aviation services,<sup>357</sup> the conditions we adopt in this order related to requirements for certified aviation GPS receivers and availability of Ligado base station deployment data for aviation stakeholders obviate these concerns. Third, we find that, based the technical studies included in the record, the lower power levels being authorized, the co-

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<sup>352</sup> Based on the information in the record, it is possible that some military receivers would perform similar to commercial high precision receivers that were tested by Ligado (i.e. they showed some impact at received power levels lower than -42 dBm, thus requiring repair or replacement). It is also possible that some military receivers are embedded in systems or platforms that cannot feasibly be replaced or repaired expeditiously and other arrangements might be required between Ligado and the federal agency.

<sup>353</sup> Air Force Feb. 2020 Memorandum at 3.

<sup>354</sup> In these cases, Ligado and the federal agency might agree to particular, limited geographic areas that cannot be served by Ligado (i.e., limited exclusion zones) thereby making expeditious repair or replacement of U.S. Government devices unnecessary.

<sup>355</sup> See, e.g., *The Federal Communications Commission and The National Telecommunications and Information Administration: Coordination Procedures in the 1695-1710 MHz and 1755-1780 MHz Bands*, GN Docket No. 13-185, Public Notice, 29 FCC Rcd 8527, 8539 (NTIA-FCC 2014). The AWS-3 Coordination Public Notice provided that, if an AWS licensee believed that a Federal incumbent was not negotiating in good faith, then NTIA could assist and the licensee would have the option of informing the Commission. *Id.* Likewise, if a Federal incumbent believed that the AWS-3 licensee was not negotiating in good faith, then it could seek NTIA's assistance. *Id.* We would expect interested parties to follow a similar practice here, to the extent they are unable to resolve any issues associated with Ligado's commitments and the conditions we adopt in this Order.

<sup>356</sup> Air Force Feb. 2020 Memorandum at 2.

<sup>357</sup> See *id.* at 3.

existence agreements Ligado has entered into with major GPS device manufacturers, and the several conditions that we adopt in this order, that concerns relating to potential harmful interference to civil GPS receivers not owned by the government<sup>358</sup> have effectively been addressed.

106. We conclude that the coordination requirements we adopt in this order, including the identification and repair or replacement of GPS devices potentially affected by Ligado's system, constitute appropriate and reasonable measures to address the federal agencies' concerns, including concerns about current "unknowns" and risks. These and related conditions are included in section G (Conditions), below.

## **2. Impacts to MSS Operations from Ligado's Proposed Operations**

### **a. Concerns regarding harmful interference to Inmarsat's MSS operations from Ligado's downlink operations in the 1526-1536 MHz band**

107. Both Ligado and Inmarsat have MSS authorizations for operation in the 1525-1559 MHz band. Some entities that access Inmarsat's MSS signals for satellite-based services, including Boeing, express concern that Ligado's proposed terrestrial downlink operations in the lower portion of the band at 1526-1536 MHz could interfere with their Inmarsat-based services.

108. Boeing expresses concern that Ligado's operations may require that Inmarsat receivers used aboard commercial and governmental aircraft need to be modified, which could involve significant cost and efforts.<sup>359</sup> In 2017, ASRI (joined by others) also expressed concern about the potential for Ligado's operations to interfere with Inmarsat-based services.<sup>360</sup> More recently, ASRI has emphasized the same concerns.<sup>361</sup>

109. In response to these concerns, Ligado argues that protection of Inmarsat's aeronautical receivers is ensured by meeting the power flux density limit of -56.8 dBW/m<sup>2</sup>/200 kHz contained in section 25.253(d)(5), to be observed "at the edges of airport runways and aircraft stand areas," including takeoff and landing paths.<sup>362</sup> Ligado further notes that an alternative total power flux density limit was previously authorized, but this alternative limit would only apply after the Inmarsat aeronautical receivers have been appropriately upgraded.<sup>363</sup> With respect to the concerns raised by Boeing about cost and efforts that would be required in this upgrading process, Ligado emphasizes that this matter should be "addressed through commercial channels."<sup>364</sup>

110. Inmarsat states that, contrary to some commenters' suggestions, Ligado's proposed operations will comply with FCC rules, and because of the Ligado-Inmarsat inter-operator cooperation agreement, there is a basis for addressing interference concerns. With respect to the extent that Inmarsat's

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<sup>358</sup> Air Force Feb. 2020 Memorandum at 3-4.

<sup>359</sup> See Boeing Company July 9, 2018 Comments at 3-4; Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 18-313 and 11-109, at 3-4 (filed Apr. 16, 2020).

<sup>360</sup> Letter from Edward A. Yorkgitis, Counsel for ASRI, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 and 12-340, at 4 (filed June 20, 2017).

<sup>361</sup> ASRI July 24, 2018 Reply at 16-18.

<sup>362</sup> Ligado July 26, 2018 Further Reply at 3-4 (citing 47 CFR § 25.253(d)(5)).

<sup>363</sup> *Id.* at 4 (citing *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3056, para. 35); see also *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3055-56, paras. 34-38 (granting Ligado waiver from the requirements of 47 CFR § 25.253(d)(5) only after Inmarsat aeronautical terminals have been modified or replaced to increase their overload threshold pursuant to coordination agreement).

<sup>364</sup> Ligado July 26, 2018 Further Reply at 3.

receivers would need to be upgraded as Ligado's network is deployed, Inmarsat states that this is a matter that should be left to the parties to address. Inmarsat supports the grant of Ligado's modification applications and "urges the Commission to act upon them promptly."<sup>365</sup>

111. *Decision.* We agree with the points raised by Ligado and Inmarsat with respect to the potential for harmful interference to Inmarsat receivers from Ligado's base stations operating in 1526-1536 MHz. As expressed in the record, emissions from Ligado's base stations must comply with the section 25.253(d)(5) power flux density limit of -56.8 dBW/m<sup>2</sup>/200 kHz at the edge of all airport runways and aircraft stand areas. We understand that Inmarsat and Ligado are currently negotiating a process for the upgrade of Inmarsat's receivers. The International Bureau's 2010 Order modifying Ligado's ATC authority stated that, in adopting its ATC rules, the Commission did not intend to prohibit L Band MSS operators from agreeing to less restrictive limitations on MSS ATC. In fact, the Commission supported and encouraged private negotiations among interested parties in the band and would consider waiver requests of these rules based on negotiated agreements.<sup>366</sup> Consistent with this approach, parties may seek a waiver of section 25.253(d)(5), after these Inmarsat receivers have been upgraded through the process agreed to between the parties, for operation subject to an alternative total power spectral density limit of a revised limit of -26.8 dBW/m<sup>2</sup> within the receiver bandwidth. Further, Ligado was previously authorized to deviate from the conditions contained in Commission rule sections 25.253(d)(6) and (d)(7), relating to applicable power flux density levels at the water's edge of any navigable waterway.<sup>367</sup> As with our decision to allow parties to seek waiver of rule section 25.253(d)(5) here, following upgrade of Inmarsat maritime receivers through a process agreed to between the parties, the parties may seek a waiver for authorization of operations at levels not in compliance with Commission rule sections 25.253(d)(6) and (d)(7).

**b. Concerns regarding harmful interference to Iridium's MSS operations from Ligado's uplink operations in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz bands**

112. We also conclude, based on the record before us, that Ligado's proposed operations in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz portions of the 1626.5-1660.5 MHz MSS L-band, as recently updated in the record, and as modified here, would not cause harmful interference to operations in the adjacent MSS band.

113. In its 2015 modification applications, Ligado proposes that uplink operations in the 20 megahertz of spectrum in the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz portions of the MSS band be subject to a more restrictive set of operational parameters than currently authorized.<sup>368</sup> Ligado proposes first that the Commission reduce the maximum EIRP for this uplink spectrum. Specifically, it proposes that this limit be reduced from 0 dBW to -7 dBW. In addition, it proposes that the maximum EIRP for the lowest five megahertz of this spectrum—that is, 1627.5-1632.5 MHz—will ramp up from -31 dBW at 1627.5 MHz to -7 dBW at 1632.5 MHz for a period of five years and then will be limited to -7 dBW for the entire segment.<sup>369</sup>

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<sup>365</sup> Inmarsat July 19, 2018 Reply at 1-2.

<sup>366</sup> *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3052-53, para. 28 (citing *ATC Report and Order*, 18 FCC Rcd at 2036, para. 143).

<sup>367</sup> *Id.* at 3055-56, paras. 34-38 (granting waiver from the requirements of 47 CFR § 25.253(d)(6)-(7) once Inmarsat maritime terminals have been modified or replaced to increase their overload threshold to a specified extent).

<sup>368</sup> See generally Ligado Dec. 31, 2015 *Ex Parte*.

<sup>369</sup> *Id.* at 3.



114. Second, Ligado further proposes stricter out-of-band emission limits than currently authorized.<sup>370</sup> Specifically, for uplink operations it proposes to:

- (1) retain a -34 dBW/MHz limit at 1625 MHz;
- (2) reduce the limit at 1610 MHz from -71 dBW/MHz to -100 dBW/MHz, and ramp up between the values at 1625 MHz and 1610 MHz;
- (3) implement a -105 dBW/MHz limit at 1608 MHz, and ramp up between the values at 1610 MHz and 1608 MHz;
- (4) reduce the limit at 1559-1608 MHz from -95 dBW/MHz to -105 dBW/MHz; and
- (5) reduce the limit at 1541-1559 MHz from -43 dBW/MHz to -105 dBW/MHz.<sup>371</sup>

For narrowband uplink, Ligado proposes to:

- (1) modify the limit at 1610-1625 MHz to ramp up from -110 dBW/700 Hz to -44 dBW/700 Hz;
- (2) modify the limit at 1608-1610 MHz to ramp up from -115 dBW/700 Hz to -110 dBW/700 Hz;
- (3) modify the limit at 1559-1608 MHz to -115 dBW/700 Hz; and
- (4) modify the limit at 1541-1559 MHz to -132 dBW/2 kHz.<sup>372</sup>

115. Several commenters express support for Ligado's proposed uplink operations and contend that its willingness to reduce the power levels and operate under stricter OOB limits at these frequencies will help protect against harmful interference to other services.<sup>373</sup> Other commenters contend that the proposed power limit reductions and changes to OOB limits are not enough to address outstanding interference concerns, including potential interference to satellite communications systems. Iridium, for example, objects to Ligado's plans and contends that Ligado's proposed operation of user terminals in the 1627.5-1637.5 MHz band, in spectrum adjacent to Iridium's operations in the 1617.775-1626.5 MHz band, would generate harmful OOB that would cause interference to Iridium end users.<sup>374</sup>

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<sup>370</sup> Ligado Dec. 31, 2015 *Ex Parte* at 3.

<sup>371</sup> *Id.*

<sup>372</sup> *Id.*

<sup>373</sup> See, e.g., Trimble May 23, 2016 Comments at 1-2 ("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"); Public Knowledge May 23, 2016 Comments at 1 ("Modifying Ligado's license conditions and permitting Ligado to begin deployment of its proposed satellite-terrestrial broadband network should provide multiple public interest benefits and, given the agreements reached between Ligado and GPS stakeholders, satisfactorily address any lingering interference concerns."); Greenwood Telecommunications Consultants, LLC May 23, 2016 Comments at 1 ("Ligado uplinks would operate in bands currently dedicated exclusively to GEO-MSS uplinks and are the farthest from the GPS/GNSS band.").

<sup>374</sup> See, e.g., Letter from Bryan N. Tramont, Counsel to Iridium Communications, Inc. to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, 12-340, Attach. at 4 (filed May 14, 2019); Letter from Bryan N. Tramont, Patrick R. Halley, Counsel for Iridium Communications, Inc. to Marlene Dortch, Secretary, FCC, IB Docket No. 11-109, 12-340, Attach. "Technical Analysis of Ligado Interference Impact on Iridium Aviation Services" at 2 (filed Dec. 14, 2016) (Iridium Dec. 14, 2016 *Ex Parte*); Letter from Bryan N. Tramont, Counsel to Iridium Communications, Inc. to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, 12-340, at 1 (filed Sept. 2, 2016) (Iridium Sept. 2, 2016 *Ex Parte*) (submitting "Technical Analysis of Ligado Interference Impact on Iridium User Links" (Iridium 2016 Technical Analysis) alleging significant risk of harmful interference that would be created by allowing Ligado the flexibility to deploy user terminals for a CMRS system in the 1627.5-1637.5 MHz band); see also Coalition of Aviation, Satellite Communications, and Weather Information Users Apr. 15, 2020 *Ex*

(continued....)

Iridium expresses concern that Ligado's proposed operations would negatively affect its services in the general terrestrial environment and would also cause interference to its SATCOM aviation services.<sup>375</sup> Iridium has requested that, in the absence of an agreement between the parties, the Commission adopt additional license conditions to ensure sufficient interference protection from Ligado's proposed operations by requiring the following: (i) reduced out-of-band emissions from Ligado's mobile terminals into Iridium's spectrum in the adjacent band below 1626.5 MHz; and (ii) exclusion zones around airport facilities to protect Iridium's Aeronautical Mobile-Satellite (Route) Service (AMS(R)S) communications at or near airports.<sup>376</sup> In response, Ligado contends that its engineering analysis demonstrates that its proposed terrestrial operations will not cause harmful interference to Iridium's operations.<sup>377</sup> It further contends that this conclusion was confirmed by the DOD-sponsored analysis conducted by Alion.<sup>378</sup> Iridium argues that Ligado's response to its engineering analysis is based on invalid assumptions and does not address the potential for interference from Ligado's proposed operations.<sup>379</sup>

116. *Decision.* With respect to the OOB limits closest to the band edge, Ligado's modification application of December 31, 2015, would be slightly more restrictive than the limits included in an unopposed waiver granted to SkyTerra in 2010, a Ligado predecessor in interest.<sup>380</sup> Specifically, SkyTerra was granted a waiver to permit its ATC mobile terminals to operate with an out-of-channel emission of -58 dBW/4 kHz at a 1 MHz offset beyond the edges of the assigned spectrum bands, which is bounded at 1626.5 MHz at the lower end.<sup>381</sup> The waiver replaced the limits in the rules adopted by the Commission in a 2005 order requiring that ATC mobile terminals operating in the 1626.5-1660.5 MHz frequency band limit their out-of-channel emissions to -67 dBW/4 kHz at the edge of the MSS licensee's "authorized and internationally coordinated MSS frequency assignment."<sup>382</sup>

117. Given the concerns raised in detail by Iridium in this record, we do not allow out-of-channel emissions generated by Ligado's ATC mobile terminals on the lower uplink channel at 1627.5-

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*Parte* at 1-2 (noting the importance of satellite services operating in the L-band for a variety of aviation, satellite communications, and weather information services and expressing general concerns that Ligado's proposed operations have not addressed concerns about harmful interference).

<sup>375</sup> Iridium Dec. 14, 2016 *Ex Parte*, Attach. at 2-3; Iridium Sept. 2, 2016 *Ex Parte*, Iridium 2016 Technical Analysis at 1-2.

<sup>376</sup> Iridium June 21, 2016 Reply at 3.

<sup>377</sup> Ligado Section 7 Request at 19; Letter from Gerard J. Waldron, Michael Beder and Hannah Lepow, Counsel to Ligado, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, 12-340 at 2, 5-7, and Attach., "Ligado's Technical Response to Iridium's December 14 Letter" (filed Jan. 17, 2017) (Ligado Jan. 17, 2017 *Ex Parte* and Technical Response); Letter from Gerard J. Waldron, Counsel to Ligado, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 and 12-340, Attach. (filed Nov. 2, 2016) (Ligado Nov. 2, 2016 *Ex Parte* and Technical Analysis).

<sup>378</sup> Ligado Section 7 Request at 19 (citing Ligado July 18, 2018 Reply at 20-21).

<sup>379</sup> Letter from Bryan N. Tramont, Patrick R. Halley, Counsel to Iridium, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109, 12-340, at 3-10 (filed March 27, 2017); Iridium Dec. 14, 2016 *Ex Parte*, Attach. at 2-6.

<sup>380</sup> See *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3056-57, para. 42.

<sup>381</sup> *Id.* When measured over the one megahertz immediately below the band edge rather than 4 kHz, the -58 dBW/4 kHz would be equivalent to -34 dBW/MHz.

<sup>382</sup> 47 CFR § 25.253(g)(1). In 2003, when the Commission adopted rules for ATC mobile terminal transmissions in the 1626.5-1660.5 MHz frequency band, it noted that Big LEO mobile earth stations operating below 1626.5 MHz, which would include those of Iridium, would need to be capable of tolerating out-of-band emissions in the range from -47 dBW/4kHz to -58 dBW/4kHz (or -23 dBW/MHz to -34 dBW/MHz). *ATC Report and Order*, 18 FCC Rcd at 2050, para. 178.

1637.5 MHz to be above the -67 dBW/4kHz limit contained in section 25.253(g)(1) adopted in 2005. The comments submitted by Iridium, however, do not offer sufficient grounds to justify imposing the requirements it suggests, and we decline to do so. The interference analysis conducted by Iridium is based on an out-of-channel emissions level that is 9 dB higher than the limit being imposed here. In addition, Iridium uses conservative assumptions with respect to the number of simultaneous interfering signals (assumed to be 18) and path loss for these signals.<sup>383</sup> Moreover, 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. Since the lower edge of Ligado's authorized and internationally coordinated MSS frequency assignment is 1627.5 MHz, we require Ligado's ATC mobile terminal emissions to be limited to -67 dBW/4kHz at 1627.5 MHz, as required by 47 CFR § 25.253(g)(1). The out-of-channel emissions limit imposed here is 9 dB more stringent than that contained in the 2010 Ligado authorization.<sup>384</sup>

118. We do not accept Iridium's request for an exclusion zone around airport facilities to protect Iridium MSS (including AMS(R)S) operations, bearing in mind Ligado's obligation to resolve harmful interference if caused to other services, such as MSS downlink operations, and without any distinction between MSS and AMS(R)S.<sup>385</sup> We encourage Iridium and Ligado, however, to engage in further discussions to address any use cases that may present unique interference concerns due to deployment patterns or operational considerations, with the aim of concluding arrangements that may be satisfactory to both parties.

119. We also adopt as conditions the additional OOB limits proposed in Ligado's modification application of December 31, 2015, at frequencies below 1625 MHz, as discussed further in section G, Conditions for ATC Authority, below.

#### **E. Waiver of ATC "Integrated Service" Rule**

120. Section 25.149(b) of the Commission's rules establishes several prerequisites—collectively known as the "gating criteria"—that an MSS operator must demonstrate it will satisfy to obtain ATC authority.<sup>386</sup> The purpose of the gating criteria is to ensure that the added terrestrial component remains ancillary to the principal MSS offering.<sup>387</sup> The gating criteria require that an MSS operator must provide "substantial" satellite service and must offer "integrated" MSS and ATC service.<sup>388</sup> Ligado obtained a waiver of the integrated service requirement of section 25.149(b)(4) of the Commission's rules as part of the *2011 Order and Authorization*.<sup>389</sup> The International Bureau determined that, in light of the totality of the facts and circumstances before it, a conditional waiver would better serve the public interest and the goals of the Commission's MSS/ATC gating criteria than would strict application of the integrated service rule.<sup>390</sup> The International Bureau granted the waiver subject to

<sup>383</sup> See Iridium Sept. 2, 2016 *Ex Parte*, Iridium 2016 Technical Analysis at 4 and 7-9. See generally Iridium Aug. 26, 2019 *Ex Parte* at 2.

<sup>384</sup> See *SkyTerra ATC Modification Order*, 25 FCC Rcd at 3056, para. 42. For Ligado's mobile terminals that operate on the upper uplink channel at 1646.5-1656.5 MHz, we continue to limit the out-of-channel emissions to -58 dBW/4 kHz at a 1 megahertz offset beyond the edges of the authorized and internationally coordinated MSS frequency assignment at 1646.5-1656.5 MHz, consistent with the 2010 waiver granted to Ligado's predecessor SkyTerra. *Id.*

<sup>385</sup> See 47 CFR § 25.255 (if harmful interference is caused to other services by ancillary MSS ATC operations, the MSS ATC operator must resolve any such interference).

<sup>386</sup> See 47 CFR § 25.149(b).

<sup>387</sup> See *ATC Report and Order*, 18 FCC Rcd at 1964-65, paras. 1-2.

<sup>388</sup> 47 CFR § 25.149(b)(1)-(5).

<sup>389</sup> *2011 Order and Authorization*, 26 FCC Rcd at 583, para. 36.

<sup>390</sup> *Id.* at 581, para. 29.

several conditions to help ensure market availability of substantial MSS and commercially competitive satellite/terrestrial services and devices.<sup>391</sup>

121. Consistent with the International Bureau's determination in 2011, we find that waiver of the integrated service requirement, subject to the conditions outlined below, does not undermine its purpose and is in the public interest.<sup>392</sup> Several of the facts and circumstances the International Bureau cited in support of Ligado's previous waiver remain applicable today. Ligado remains a significant and substantial provider of MSS. Ligado has invested over \$1 billion in the development and enhancement of its MSS network and systems, including its SkyTerra 1 satellite—a 22-meter, reflector-based antenna enabling high-quality connectivity to low-power, small-form factor devices throughout North America.<sup>393</sup> Ligado continues to collaborate with Inmarsat to rationalize the parties' L-band spectrum, pursuant to a coordination arrangement between the two entities.<sup>394</sup> Ligado is also working with Ericsson to develop a satellite adaptation of the 3GPP LTE-M and NB-IoT standards.<sup>395</sup> Ligado has already developed a standardization plan in 3GPP for the 30 megahertz of spectrum subject to this order, as part of 3GPP Band 24.<sup>396</sup> Ligado plans to go back to 3GPP for any required modifications and will convert Band Class 24 to 5G Band n24, which will allow this spectrum to also be used with the 5G-NR standard.<sup>397</sup> Finally, we impose several waiver conditions below to ensure consistency with the purposes of the gating criteria and the integrated service rule (mainly, to continue to ensure that Ligado's terrestrial-based services remain ancillary to its MSS-based offering), similar to those the International Bureau adopted in 2011.

#### F. Spectrum Management Coordination with NTIA

122. The Communications Act charges the Commission with the licensing and regulation of commercial and private spectrum use,<sup>398</sup> while NTIA has been delegated authority over radio stations “belonging to and operated by the United States.”<sup>399</sup> The Commission and NTIA coordinate their respective spectrum management responsibilities pursuant to a Memorandum of Understanding (MOU), with the goal of promoting the efficient use of the radio spectrum in the public interest.<sup>400</sup> In this MOU,

<sup>391</sup> 2011 Order and Authorization, 26 FCC Rcd at 583, para. 36.

<sup>392</sup> See *infra* section III.H.6. The Commission may waive any provision of its rules “if good cause therefore is shown” and may find good cause to extend a waiver “if special circumstances warrant a deviation from the general rule and such deviation will serve the public interest.” 47 CFR § 1.3; *Northeast Cellular Telephone Co. v. FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir. 1969), *aff'd*, 459 F.2d 1203 (1972), *cert. denied*, 409 U.S. 1027 (1972).

<sup>393</sup> See Ligado Networks, Satellite Network, SkyTerra 1 Satellite, <https://ligado.com/technolog/satellite/> (last visited Aug. 13, 2019).

<sup>394</sup> See, e.g., Inmarsat Group Ltd. Interim Results 2016 – Supplemental Disclosure at 4 (Sept. 14, 2016), <https://www.inmarsat.com/wp-content/uploads/2016/09/Supplemental-disclosure-document-14-September-2016.pdf> (last visited Aug. 13, 2019) (noting that in April 2016, Ligado Networks made an election under its Cooperation Agreement with Inmarsat to use Inmarsat's existing L-band spectrum in the U.S., requiring Inmarsat to provide its services across smaller allocations of spectrum in exchange for future payments).

<sup>395</sup> See Ligado Aug. 6, 2019 *Ex Parte* at 6.

<sup>396</sup> *Id.*

<sup>397</sup> *Id.*

<sup>398</sup> 47 U.S.C. 151, 301.

<sup>399</sup> 47 U.S.C. 305(a); 47 U.S.C. 902(b)(2)(A) (delegating authority to regulate government radio stations to NTIA).

<sup>400</sup> Memorandum of Understanding Between the Federal Communications Commission and the National Telecommunications and Information Administration, at 1 (Jan. 31, 2003), <https://docs.fcc.gov/public/attachments/DOC-230835A2.pdf> (FCC-NTIA MOU).

the agencies are committed to performing their respective obligations in a cooperative manner to ensure that the spectrum is used for its highest and best purpose.<sup>401</sup> Pursuant to the MOU, the staffs of the Commission and NTIA meet regularly to exchange information. The Commission endeavors to provide NTIA notice of all proposed actions that could potentially cause interference to government operations, giving NTIA time to comment prior to final action by the Commission; NTIA similarly provides notice to the Commission of all proposed actions that could potentially cause interference to non-government operations.<sup>402</sup> Wherever possible, the MOU provides that the Commission and NTIA will resolve technical, procedural, and policy differences by consensus.<sup>403</sup> Final action by either agency, however, “does not require approval” of the other.<sup>404</sup>

123. Consistent with the MOU, the Commission and the NTIA have exchanged information concerning the issues in this proceeding since 2011 and have been exchanging information on potential MSS/ATC operations since 2003, when the Commission first established rules to permit MSS licensees to seek authority to operate ATC stations. As discussed in this Order, NTIA has submitted several formal responses in this proceeding, sharing its views in 2011, 2012, 2014, and, with respect to Ligado’s modified applications since 2015, in December 2019 and April 2020.

124. In its December 6, 2019 submission, the NTIA stated that “the assessment of the potential impacts of Ligado’s proposals has been thorough,” specifically citing several technical studies that are part of the record before the Commission, including the 2018 DOT ABC Study, the 2017 NASCTN Report, the 2016 RAA Report, the 2011 and 2012 NPEF reports, and the 2011 TWG Report.<sup>405</sup> NTIA further states that, based on the assessments of the potential impacts of Ligado’s proposals in the record, federal agencies have “significant concerns” regarding the impacts to their missions, national security, and the U.S. economy.<sup>406</sup> NTIA concludes that, despite the considerable efforts to find a satisfactory solution, it, on behalf of the executive branch, was “unable to recommend” the Commission’s approval of the Ligado applications.<sup>407</sup> As part of its submission, NTIA enclosed three letters – a December 2018 letter to NTIA from the National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT EXCOM) recommending that any current or future proposals to operate commercial services in bands adjacent to GPS should not be approved unless, at a minimum, they do not exceed the “tolerable power transmission limits” described in the DOT ABC Report,<sup>408</sup> and two letters submitted by DOD to the Commission in June 2019 and November 2019 in which DOD points to the recommendation of the 2018 PNT EXCOM and the transmission limits set forth in the DOT ABC Report and states DOD’s belief that there are too many “unknowns” and risks to federal operations, including a potential significant negative impact on military operations, to allow Ligado’s proposed system to proceed.<sup>409</sup>

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<sup>401</sup> FCC-NTIA MOU at 2.

<sup>402</sup> *Id.* Under the terms of the MOU, each party commits, where possible, to provide the other with an opportunity to comment and a minimum of 15 business days before final action. *Id.*

<sup>403</sup> *Id.* at 3.

<sup>404</sup> *Id.* at 2-3.

<sup>405</sup> NTIA Dec. 6, 2019 Letter at 2 & n.7.

<sup>406</sup> *Id.* at 2.

<sup>407</sup> *Id.*

<sup>408</sup> *Id.*, Enclosure 1 (letter from Dana Deasy and Heidi R. King, Acting Co-Chairs, EXCOM, to David J. Redl, Assistant Sec’y for Communications & Information, NTIA, (Dec. 3, 2018)).

<sup>409</sup> *Id.*, Enclosure 2 (Letter from Mark T. Esper, Sec’y, Department of Defense, to Ajit Pai, Chairman, FCC (Nov. 18, 2019) (DOD Nov. 18, 2019 Letter) (stating that, pursuant to 10 U.S.C. § 2281, the Secretary of Defense may not agree to any restriction on GPS that would adversely affect the military potential of GPS); Enclosure 3 (Letter from Patrick M. Shanahan, Acting Sec’y, Department of Defense, to Ajit Pai, Chairman, FCC (June 7, 2019) (DOD June

(continued....)

125. In its April 10, 2020, submission NTIA states that it believes that the Commission “cannot reasonably reach” a conclusion that harmful interference concerns have been resolved.<sup>410</sup> Neither NTIA’s letter nor the enclosed Air Force memorandum or DOD letters include any new technical data.<sup>411</sup> The Air Force contends that Ligado’s proposed license modification would implicate a large number of systems and would threaten disruption of GPS, which would cause unacceptable operational impacts and adversely affect the military potential of GPS by negatively impacting GPS receivers.<sup>412</sup> According to the Air Force, the measures that Ligado has proposed are “impractical and un-executable in that they would shift the risk of interference to, and place enormous burdens on, agencies and other GPS users to monitor and report the interference.”<sup>413</sup> The Air Force further contends that it would be “practically impossible” for DOD to identify and repair or replace all of the potentially affected legacy receivers, that it could take years, and that the time required to modify or replace affected receivers could jeopardize DOD forces and warfighting capabilities.<sup>414</sup>

126. Although NTIA states that it is unable to recommend the Commission’s approval of Ligado’s applications,<sup>415</sup> and states its own belief that the Commission “cannot reasonably reach” a conclusion that harmful interference concerns have been resolved,<sup>416</sup> for the reasons set forth in this Order, including our thorough evaluation of the technical assessments before us that include those cited by NTIA in its letters, we conclude that approval of Ligado’s modified applications, with the stringent conditions that we impose, will effectively address and resolve the potential harmful interference concerns relating to Ligado’s proposed operations and will promote the efficient use of spectrum in the public interest. As noted by Ligado, NTIA’s December 6, 2019 letter, conveys no new information, data, or arguments that are not already in the record before us, and makes no recommendation to the Commission,<sup>417</sup> and the attached DOD letters similarly contain no data, analysis, or basis for their conclusion other than pointing to the PNT EXCOM recommendation and the DOT ABC Report,<sup>418</sup> both of which rely on the 1 dB metric that we have not found persuasive. Similarly, NTIA’s April 10, 2020 letter and enclosures contain no new technical data for the Commission’s consideration, and the Air Force similarly relies on the 1 dB metric for its underlying assessment of potential harmful interference.<sup>419</sup> For

(Continued from previous page) \_\_\_\_\_

7, 2019 Letter) at 1 (same). Beyond reference to the DOT ABC Report, these letters do not provide any mention or discussion of any technical analyses in the record in this proceeding.

<sup>410</sup> NTIA Apr. 10, 2020 Letter at 2. In its letter, NTIA noted that the International Bureau’s *2011 Order and Authorization* provides that the process for authorizing ATC operations would be complete “once the Commission, after consultation with NTIA, concludes that the harmful interference concerns have been resolved.” *Id.*

<sup>411</sup> See generally NTIA Apr. 10, 2020 Letter; Air Force Feb. 2020 Memorandum; DOD Mar. 24, 2020 Letter; DOD Mar. 12, 2020 Letter.

<sup>412</sup> Air Force Feb. 2020 Memorandum at 1.

<sup>413</sup> *Id.* at 1-2.

<sup>414</sup> *Id.* at 5.

<sup>415</sup> NTIA Dec. 6, 2019 Letter at 2.

<sup>416</sup> NTIA Apr. 10, 2020 Letter at 2.

<sup>417</sup> Ligado Dec. 9, 2019 *Ex Parte* at 1-2.

<sup>418</sup> NTIA Dec. 6, 2019 Letter, Enclosures 2-3. Beyond reference to the DOT ABC Report, these letters do not provide any mention or discussion of any technical analyses in the record in this proceeding. *Id.*; see also Ligado Jan. 21, 2020 *Ex Parte* at 1 (DOD’s November 2019 letter contained no data, no analysis, and no basis for its conclusion other than the DOT ABC Report, which has been before the Commission since filed by Ligado in April 2018).

<sup>419</sup> See generally NTIA Apr. 10, 2020 Letter; Air Force Feb. 2020 Memorandum; DOD Mar. 24, 2020 Letter; DOD Mar. 12, 2020 Letter.

the reasons set forth in detail in this Order, we conclude that use of the 1 dB metric approach is inconsistent with established spectrum management policies designed to avoid harmful interference, and is also unsupported by the record.<sup>420</sup>

127. We disagree with the contention in the Air Force memorandum that Ligado's commitment to identify and repair or replace potentially affected legacy equipment "is not feasible, affordable or technically executable."<sup>421</sup> Ligado's reduced power levels, the co-existence agreements it has entered into with major GPS device manufacturers, and the information-sharing and cooperation conditions that we adopt in this Order all support our conclusion that the potential for harmful interference to U.S. Government GPS receivers is limited and manageable.

128. Finally, we find that the Commission has satisfied the consultation with NTIA anticipated by the 2011 Order and Authorization. The operating parameters that we are authorizing in this Order, along with the extensive conditions that we adopt, are designed to ensure protection of federal GPS and other stakeholders in the relevant bands.<sup>422</sup>

### **G. Compliance with Section 343 of the Communications Act**

129. Through our decision in this Order and Authorization and the strict conditions that we adopt, the Commission is complying with the requirements of section 343 of the Communications Act. Section 343 states that the Commission shall not permit commercial terrestrial operations in the 1525-1559 MHz or 1626.5-1660.5 megahertz bands until 90 days after the Commission "resolves concerns of widespread harmful interference by such operations" in those bands "to covered GPS devices"<sup>423</sup>—i.e., those used by the Department of Defense.<sup>424</sup>

130. As discussed in this Order and Authorization, we find that concerns of widespread harmful interference relating to GPS are effectively resolved based on the parameters of Ligado's amended modification applications, the test data/analyses presented in the record, and the conditions imposed in this Order and Authorization, which address any identified potential harmful interference concerns before ATC network operations commence. Condition 2 prohibits Ligado from commencing ATC operations in its L-Band spectrum until at least 90 days from adoption of this Order,<sup>425</sup> consistent

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<sup>420</sup> As Ligado notes, the Air Force memorandum does not provide the "specific relevant information about affected GPS receivers" that the Commission requested in its 2016 public notice on Ligado's license modification applications. Ligado Apr. 12, 2020 *Ex Parte* at 7 (quoting 2016 *Comment PN*, 31 FCC Rcd at 3809).

<sup>421</sup> See generally NTIA Apr. 10, 2020 Letter; Air Force Feb. 2020 Memorandum; DOD Mar. 24, 2020 Letter; DOD Mar. 12, 2020 Letter.

<sup>422</sup> The DOD has stated that, pursuant to 10 U.S.C. § 2281, it "may not agree to any restriction on the GPS system that 'would adversely affect the military potential' of GPS." See, e.g., DOD Nov. 18, 2019 Letter; DOD Mar. 24, 2020 Letter. We agree with Ligado that the language, purpose, and history of this provision do not demonstrate any intention by Congress to divest the Commission of its broad and well-established spectrum management authority over spectrum allocated for commercial use under Title III of the Communications Act. Ligado Apr. 12, 2020 *Ex Parte* at 8-10. Section 2281 was enacted in 1997, and the relevant language is addressed to DOD's obligations in connection with its consultations with specified Executive Branch agencies and others regarding nonmilitary uses of GPS, not the Commission's regulation of commercial spectrum for other services in other bands. Whatever the limits of the scope of nonmilitary uses of GPS to which DOD "may not agree," it is the Commission that is vested with Title III authority to determine how to manage spectrum use. We believe that our determination to discharge that obligation here is consistent with well recognized principles of spectrum management and supported by substantial evidence in the record.

<sup>423</sup> 47 U.S.C. § 343(a).

<sup>424</sup> 47 U.S.C. § 343(c).

<sup>425</sup> See *infra* section H, Conditions for ATC Authority.

with section 343's requirement that Ligado not begin terrestrial operations until 90 days after the Commission resolves widespread harmful interference concerns.<sup>426</sup> Condition 4 of this Order, which concerns the GPS devices covered under section 343, requires that Ligado cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's ATC operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program to repair or replace any such devices that is consistent with that agency's programmatic needs, as well as requiring Ligado to provide no less than six-months' notice of activation of any base station transmitting in the 1526-1536 MHz band to GPS manufacturers.<sup>427</sup> These particular conditions provide further protection to covered GPS devices intended to be protected under section 343. Finally, we note that section 343 also requires the Commission to submit to Congress copies of the Commission's Order and Authorization, as it sets forth the explanation of how interference concerns have been resolved.<sup>428</sup> Accordingly, we direct that the Commission's Office of Legislative Affairs submit this Order and Authorization to the Committee on Energy and Commerce and the Committee on Armed Services of the U.S. House of Representatives and the Committee on Commerce, Science, and Transportation and the Committee on Armed Services of the U.S. Senate.

## **H. Conditions for ATC Authority**

131. For the reasons stated above, we grant Ligado's amended modification applications, subject to the strict conditions imposed herein. As a condition of its ATC authority, Ligado shall comply with the conditions set forth below (collectively, the Conditions). All Conditions apply to any successor-in-interest or assignee of Ligado. The Conditions largely have been proposed or already agreed to by Ligado, either in its filings or in its agreements with GPS manufacturers. To the extent discussed herein, we are accepting Ligado's proposals and making them Conditions of this license grant. To the extent that we impose further obligations to this grant requiring stricter and/or additional compliance measures than those specified in Ligado's proposals, the Conditions govern. Failure to comply with these Conditions may subject Ligado to monetary forfeitures and/or the partial loss of ATC authority in a relevant geographic area based upon the type and scope of violation, or complete loss of such ATC authority.

132. As discussed previously, the Bureaus found it in the public interest to toll previously imposed build-out conditions until further determinations were made with respect to Ligado's ATC authority.<sup>429</sup> Today we fully address Ligado's ATC authority and, absent further action, the prior tolling of Ligado's build-out obligations would cease. As these build-out conditions were specifically applicable to the then-proposed nationwide 4G mobile broadband network authorized under substantially higher transmit power levels and other less restrictive technical parameters, including proposed downlink operation at 1545-1555 MHz, we terminate the build-out obligations set forth in Attachment 2, Condition 2 of the *SkyTerra TOC Order*. Further, unless otherwise stated herein, the Conditions we impose below

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<sup>426</sup> We direct OLA to submit two copies of this Order and Authorization to the congressional committees specified in Section 343(b)(2).

<sup>427</sup> See *supra* section H, Conditions for ATC Authority.

<sup>428</sup> See 47 U.S.C. § 343(b) (requiring the Commission "to submit to the congressional committees described in paragraph (2) official copies of the documents containing the final decision of the Commission. If the decision is to permit such operations in such band, such documents shall contain or be accompanied by an explanation of how the concerns described in subsection (a) have been resolved").

<sup>429</sup> See *2012 Tolling Order*, 27 FCC Rcd at 15886, para. 13.



on Ligado's ATC authority supersede those imposed on Ligado in prior Commission orders,<sup>430</sup> and Ligado remains subject to the Commission ATC rules,<sup>431</sup> unless otherwise waived herein.

### 1. Compliance with GPS Co-Existence Agreements

133. Ligado shall comply fully with any and all terms and conditions set forth in its currently effective agreements with the following GPS manufacturing entities: Garmin International, Inc.,<sup>432</sup> Trimble Navigation Limited,<sup>433</sup> Deere & Company,<sup>434</sup> NovAtel, Inc.,<sup>435</sup> Topcon Positioning Systems, Inc.,<sup>436</sup> and Hexagon Positioning Intelligence.<sup>437</sup> To the extent that these agreements are further amended or modified, Ligado shall comply with any and all amended or modified terms and conditions not inconsistent with these Conditions. Further, to the extent Ligado enters into new co-existence agreements with additional GPS manufacturers, Ligado shall comply with any and all terms and conditions not inconsistent with these Conditions set forth in such additional agreements and any related amendments.

### 2. Power Levels and Operating Restrictions

134. *Downlink Power Level.* Consistent with the DOT ABC Report and Ligado's May 31, 2018 amendment (in fulfillment of its December 2015 commitment to abide by the recommendation of the FAA), Ligado's ATC base stations operating in the 1526-1536 MHz band shall not exceed an EIRP of 9.8 dBW (10 W) with a +/- 45 degree cross-polarized base station antenna. Based on FAA analysis, the minimum inter-station separation distance shall be 433 meters in a hexagonal grid.

135. *Uplink Power Level.* Consistent with Ligado's agreements with the GPS companies, Ligado shall not exceed a power level of -7 dBW in the 1627.5-1637.5 MHz and the 1646.5-1656.5 MHz uplink bands, but that, for a period of five years, the maximum EIRP for the lowest five megahertz of this spectrum—that is, 1627.5-1632.5 MHz—will ramp up from -31 dBW at 1627.5 MHz to -7 dBW at 1632.5 MHz before becoming subject to the -7 dBW limit for the entire segment.

136. *No Terrestrial Operation in the Upper-Downlink Band.* Consistent with its agreements with the GPS companies and its May 2018 amendment, Ligado shall not operate using its ATC authority in its MSS downlink spectrum from 1545-1555 MHz.

137. *ATC Base Station Limitation in Lower Downlink.* Consistent with its May 2018 amendment (incorporating the FAA's assessment in the DOT ABC Report), Ligado shall be prohibited from operating any ATC base station antenna in its lower downlink band, 1526-1536 MHz, at a location less than 250 feet laterally or less than 30 feet below an obstacle clearance surface established by the FAA under 14 CFR Part 77 and implementing orders and decisions. To ensure compatibility with 14 CFR Part

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<sup>430</sup> See 2004 ATC Authorization Order, 19 FCC Rcd 22144; *SkyTerra ATC Modification Order*, 25 FCC Rcd 3043; *SkyTerra TOC Order*, 25 FCC Rcd 3059; 2011 Order and Authorization, 26 FCC Rcd 566. We remind Ligado that, as a general rule, wireless operation must not cause harmful interference across the Canadian and Mexican borders. While there are no current international agreements between and among the United States, Mexico and Canada with regard to the subject bands 1525-1559 and 1626.5-1660.5 MHz for exchange of specific station information concerning ATC operations, Commission licensees will be subject to any future agreements between and among the United States, Mexico, and Canada concerning ATC operations.

<sup>431</sup> See 47 CFR Part 25.

<sup>432</sup> See Ligado Dec. 17, 2015 *Ex Parte* and Garmin Agreement.

<sup>433</sup> See Ligado Feb. 3, 2016 *Ex Parte* and Trimble Agreement.

<sup>434</sup> See Ligado Dec. 8, 2015 *Ex Parte* and Deere Agreement.

<sup>435</sup> See NovAtel Jun. 27, 2016 *Ex Parte* (referencing co-existence agreement between NovAtel and Ligado).

<sup>436</sup> See Topcon Nov. 29, 2016 *Ex Parte* (referencing cooperation agreement between Topcon and Ligado).

<sup>437</sup> See Hexagon May 7, 2018 *Ex Parte* (referencing agreement between Hexagon and Ligado).

77, no Ligado tower may be located such that the 250-foot standoff cylinder would pierce the obstacle clearance surface.

138. *Commencement of operations.* Ligado shall be prohibited from commencing commercial terrestrial operations in the 1525-1559 or the 1626.5-1660.5 MHz bands until at least 90 days from the release of this Order and Authorization. However, for commercial terrestrial operations in the 1526-1536 MHz band, Ligado shall also comply with the additional temporal restrictions in Condition 4, below, prior to commencing operations.

### 3. Out-of-Band Emissions

139. *ATC Mobile Terminal Emissions.* Consistent with the decisions above and Ligado's commitment in the 2015 modification applications, the EIRP for Ligado's ATC mobile terminal out-of-channel emissions shall be limited to:

- (i) -67 dBW/4kHz at 1627.5 MHz;
- (ii) a level determined by linear interpolation from -67 dBW/4kHz at 1627.5 MHz to -100 dBW/MHz at 1610 MHz in the 1627.5-1610 MHz frequency range;
- (iii) a level determined by linear interpolation from -100 dBW/MHz at 1610 MHz to -105 dBW/MHz at 1608 MHz in the 1610-1608 MHz frequency range;
- (iv) -105 dBW/MHz in the 1541-1608 MHz frequency range;
- (v) -58 dBW/4 kHz at a 1 megahertz offset beyond the edges of the authorized and internationally coordinated MSS frequency assignment at 1646.5-1656.5 MHz.

140. *ATC Mobile Terminal Discrete Emissions.* Consistent with its commitment in the 2015 modification applications, the EIRP for Ligado's ATC mobile terminal discrete emissions shall be limited to:

- (i) a level determined by linear interpolation from -44 dBW/700 Hz at 1625 MHz to -110 dBW/700 Hz at 1610 MHz in the 1625-1610 MHz frequency range;
- (ii) a level determined by linear interpolation from -110 dBW/700 Hz at 1610 MHz to -115 dBW/700 Hz at 1608 MHz in the 1610-1608 MHz frequency range;
- (iii) -115 dBW/700 Hz in the 1608-1559 MHz frequency range;
- (iv) -132 dBW/2 kHz in the 1559-1541 MHz frequency range.

141. *ATC Base Station Emissions.* Consistent with its commitment in the 2015 modification applications, the EIRP for Ligado's ATC base station emissions shall be limited to:

- (i) -85 dBW/MHz in the 1541-1559 MHz and 1610-1650 MHz frequency ranges;
- (ii) -100 dBW/MHz in the 1559-1610 MHz frequency range.

142. *ATC Base Station Discrete Emissions.* Consistent with its commitment in the 2015 modification applications, the EIRP for Ligado's ATC base station discrete emissions shall be limited to:

- (i) -112 dBW/2 kHz in the 1541-1559 MHz frequency range;
- (ii) -110 dBW/700 Hz in the 1559-1610 MHz frequency range;
- (iii) -95 dBW/700 Hz in the 1610-1650 MHz frequency range.

143. *Equipment Authorization.* Ligado shall ensure that test results demonstrating compliance with the foregoing limits on emissions in the 1559-1610 MHz band are included in any application for

equipment authorization pursuant to 47 CFR Part 2 and Commission rule section 25.149(c)<sup>438</sup> for mobile terminals that would be used to communicate via Ligado's ATC network.

#### 4. Notification and Coordination

144. *Coordination with Federal Agency GPS Users.* Consistent with its commitment in the record,<sup>439</sup> Ligado shall expeditiously replace or repair as needed any U.S. Government GPS devices that experience or are likely to experience harmful interference from Ligado's operations. Ligado shall launch a program to facilitate the exchange of information between it and the U.S. Government within six months of the release of this Order and Authorization or no less than 30 days prior to the deployment of a downlink base station at 1526-1536 MHz under ATC authority, whichever is sooner. Specifically, Ligado must cooperate directly with any U.S. government agency that anticipates that its GPS devices may be affected by Ligado's ATC operations by: (1) providing base station location information and technical operating parameters to federal agencies prior to commencing operations in the 1526-1536 MHz band; (2) working with the affected agency to identify the devices that could be affected; (3) working with the affected agency to evaluate whether there would be harmful interference from Ligado's operations; and (4) developing a program to repair or replace any such devices that is consistent with that agency's programmatic needs, as well as applicable statutes and regulations relating to the ability of those agencies to accept this type of support. Furthermore, if an affected agency determines, based on the base station and technical operating data made available to it, that Ligado's operations will cause harmful interference to a specific, identified GPS receiver operating on a military installation and that the GPS receiver is incapable of being fully tested or replaced, Ligado shall negotiate with the affected government agency to determine an acceptable received power level over the military installation. Ligado shall also make available technical experts to support the repair and replacement program. In addition, Ligado shall comply with the related reporting requirements in section 7 of these Conditions.

145. *Coordination with GPS Device Manufacturers.* Ligado shall provide no less than six months advance notice regarding the activation of any base station transmitting in the 1526-1536 MHz band to:

- (i) the following GPS manufacturing companies and any successors-in-interest: Garmin International, Inc.; Trimble Navigation Limited; Deere & Company; NovAtel, Inc.; Topcon Positioning Systems, Inc.; Hexagon Positioning Intelligence; Septentrio; and Leica Geosystems, and
- (ii) any other GPS manufacturing company that Ligado knows or reasonably should know could potentially be affected by Ligado's ATC network operations.<sup>440</sup>

Advance notice must include a coverage map showing, by county, the locations where Ligado's and its customers' terrestrial network will provide coverage based upon the base station(s) to be activated (for which Ligado is providing notice), as well as existing, previously activated base stations transmitting in the 1526-1536 MHz band. Ligado shall also provide updated coverage maps to the GPS manufacturing companies covered by subsections (i) and (ii) of this provision, and any successors-in-interest, every six months following its provision of the initial coverage map.

146. *Responsiveness to and Notification of Interference Complaints.* Consistent with its May 2018 amendment, Ligado shall, prior to the deployment of any downlink base station under ATC authority in the 1526-1536 MHz band, establish and maintain a toll-free telephone number (to be made

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<sup>438</sup> 47 CFR § 25.149(c).

<sup>439</sup> See Ligado Aug. 6, 2019 *Ex Parte* at 8-9.

<sup>440</sup> We note that this would include GPS device manufacturers that have participated in the tests conducted in this proceeding or have commented in this proceeding, such as u-blox. See, e.g., u-blox June 15, 2016 Reply.

prominently available on its website while ensuring web search optimization) for the public to report apparent incidences of interference from Ligado's operations to GPS operations.<sup>441</sup> Upon receipt of a report of GPS disruption, or becoming aware that licensed operating parameters have been exceeded (e.g., maximum power level, maximum authorized bandwidth, out-of-band emissions), Ligado shall notify the Commission's Operations Center within one hour by e-mail at [FCCOPS@fcc.gov](mailto:FCCOPS@fcc.gov) and voice at (202) 418-1122. This is a 24/7 response requirement. The notification shall include, at a minimum, details of the disruption, contact name of any complaining third party, location of the disruption (lat/long), start date and time of event, and anticipated measures to be taken to resolve the disruption. If the report was generated from Ligado's or a customer's network monitoring, Ligado shall specify the technical operating parameters that have been exceeded. Upon receipt of a GPS disruption notification from Ligado, a federal partner, or other source, the FCC Operations Center may request that Ligado validate its operation in and around the area of the GPS disturbance and provide relevant technical information to the FCC Operation Center within one hour of the request. This also is a 24/7 response requirement. Ligado shall maintain "stop buzzer" capability such that, in the event of a large-scale disruption to GPS, it can cease transmissions of all base station transmitters within the radio horizon of the impacted area within 15 minutes of an FCC Operations request. In any instance not requiring stop buzzer implementation, Ligado must investigate the complaint and, if Ligado verifies it is the source of interference, resolve such interference within 24 hours of complaint receipt. Ligado also must comply with the related reporting requirement in Section 7 of these Conditions.

## **5. Base Station Database, Drive-Testing, and Monitoring**

147. *Database of Base Station Locations.* Consistent with its commitment in the record,<sup>442</sup> Ligado must work with relevant stakeholders, including ASRI, to establish a database available to the affected aviation community and include the base station information at least 30 days before commencing transmission at a base station site. The database must include, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. This will ensure that relevant technical parameters are disseminated to the affected aviation community prior to Ligado commencing any ATC operations in this spectrum. Ligado must also update the database to enter the required base station technical parameters for any subsequently activated base station at least 30 days prior to commencing any transmission. In the event that the relevant parties agree to use this database to facilitate the information-sharing requirements adopted in this order for the benefit of affected U.S. government agencies, these requirements will apply with equal force and effect to information provided pursuant to those requirements.

148. *Drive-Test Requirement.* Ligado must conduct drive testing to assess actual transmit power levels in the 1526-1536 MHz band to further ensure its deployed transmit power levels are consistent with these Conditions and its coordination obligations (e.g., providing coverage maps and monitoring base station transmit power) with GPS device manufacturers. No later than 6 months following its initial base station deployments, Ligado shall conduct a drive test<sup>443</sup> for each of its deployed

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<sup>441</sup> While we require the establishment of a toll-free number, we seek to limit frivolous complaints of interference, and anticipate that the vast majority of reporting entities would include federal partners or other knowledgeable GPS industry professionals that are well informed regarding the type of GPS disruption warranting Commission intervention.

<sup>442</sup> Ligado July 19, 2018 Reply at 11.

<sup>443</sup> We anticipate that the testing will be conducted using a similar methodology to the testing conducted by Roberson and Associates in 2011 in Washington, D.C. and Houston, TX (demonstrating terrestrial power levels as deployed were in fact lower than authorized power levels).

areas. Thereafter, Ligado shall conduct drive tests for each of its subsequently deployed areas every six months. Ligado shall comply with the related reporting requirements described in Section 7 of these Conditions.

149. *Monitoring.* Consistent with its May 2018 amendment, Ligado will maintain network operations center procedures for 24/7 continuous monitoring of the transmit power for each base station site.

## **6. Integrated Service Rule Waiver**

150. We adopt several conditions attendant to our waiver of the integrated service rule. Specifically, we require the following:

### *(i) Ensuring Market Availability of Substantial MSS*

- Ligado shall continue to make available and actively market a commercially competitive satellite service.
- Ligado shall continue to dedicate at least 6 MHz of MSS L-band spectrum, nationwide, exclusively to satellite service.
- Ligado shall continue to ensure that its satellite(s) are capable of operating across the entirety of Ligado's MSS L-band spectrum.
- Ligado shall continue to ensure that satellite-capable devices (both integrated MSS/ATC devices and satellite-only devices) using its MSS L-band spectrum are capable of operating across the entirety of Ligado's MSS L-band spectrum.

### *(ii) Ensuring Market Availability of Commercially Competitive 5G Satellite/Terrestrial Services and Devices;*

- Ligado shall offer commercial satellite access agreements to terrestrial network operators on competitive pricing terms to enable integrated satellite and terrestrial service offerings for IoT.
- Ligado shall ensure that dual-mode MSS/ATC-capable L-Band IoT devices are available in the marketplace no later than September 30, 2024.
- Ligado shall undertake to standardize satellite IoT technology in 3GPP to enable incorporation of satellite connectivity into chipsets consistent with its commitments to operate a satellite IoT network using such standards-based technology and to facilitate market participation through network access agreements for satellite IoT.
- Ligado shall ensure that it has the network capability to support MSS/ATC IoT devices and services using such standards-based technology.
- Ligado shall not offer preferential terms for the use of Ligado's spectrum for terrestrial-only service, or otherwise discourage the availability or use of combined MSS/ATC services in addition to terrestrial-only services.

## **7. Reporting Requirements**

151. *Information Exchange Quarterly Reports.* Ligado shall file quarterly reports with the Commission in IB Docket Nos. 11-109 and 12-340 commencing the first full quarter following the establishment of the information exchange program detailed in Section 4 of these Conditions. Such reports shall update the Commission regarding the status and progress on Ligado's program to exchange information with federal agency GPS users, including the components of the cooperation set forth in section 4 related to deployment of base stations, identification of potentially affected devices, evaluation of risk of harmful interference from Ligado's ATC operations to such devices, and development of a repair or replace program to meet federal agencies' needs.

152. *FCC and FAA Downlink Operations Reports.* Consistent with its May 2018 amendment, at least 30 days before commencing transmission at a base station site, Ligado shall submit to the FCC and the FAA a report that includes, at a minimum: (1) location of the proposed base station antenna site (latitude and longitude); (2) base station antenna radiation center height above ground level; (3) base station antenna tilt for both mechanical and electrical tilt; and (4) base station antenna specification, including polarization and pattern. Ligado shall certify in its reports to the FCC and FAA prior to commencing operations that a database of base station information accessible to FAA stakeholders (required under section 5 of these Conditions) has been created and is operational.<sup>444</sup>

153. *Interference Complaint Reports.* Ligado shall file quarterly reports with the Commission IB Docket Nos. 11-109 and 12-340, commencing the first full quarter following the initial deployment of any downlink base station under ATC authority in the 1526-1536 MHz band, detailing any interference complaints received (or confirming the absence of such complaints in a given quarter), how the complaints were resolved, and the timeframe for such resolution.

154. *Deployment and Drive Test Reports.* Commencing six months after the release of this Order and Authorization, Ligado shall file status reports with the Commission every six months in IB Docket Nos. 11-109 and 12-340 detailing its spectrum use plan for its network deployments, any partnership agreements Ligado has entered into with carriers or other parties for custom private solutions, for example, and the number and status of actual deployments, including the types of industries/other types of customers served and the service provided. After Ligado conducts the initial drive tests required under section 5 of these Conditions, Ligado shall file a supplement to its deployment report that includes the drive test results. Ligado shall maintain the results of subsequent drive tests required by Section 5 of these Conditions for Commission inspection upon request.

155. *Integrated Service Rule Waiver Reports.* Ligado shall submit to the Commission in IB Docket Nos. 11-109 and 12-340, beginning on April 30, 2025, semi-annual filings that estimate the number of terminals on, and active users of, its network that fall under each of the following categories MSS-only; MSS/ATC; and terrestrial-only. The information contained in these filings shall be current as of the end of the calendar quarter (i.e., March 31 or September 30) immediately preceding the date the filing is due to be filed with the Commission. Further, Ligado shall submit to the Commission, beginning on April 30, 2025, quarterly filings that identify the availability of dual-mode components (including, chipsets and RF elements) from mainstream component supplier(s). The information contained in these filings shall be current as of the end of the calendar quarter (i.e., March 31, June 30, September 30, or December 31) immediately preceding the date the filing is due to be filed with the Commission.

#### IV. CONCLUSION

156. The Commission continues to seek effective ways to promote more efficient spectrum use to meet ever-increasing demand for this limited resource by a wide variety of users. Today's action creates a path forward for Ligado to harness its MSS network and ancillary terrestrial operations to deploy a low-power terrestrial network in support of IIoT services and custom private network solutions, and to partner with carriers to support more broad-based 5G deployment.

157. In reaching our decision today, we recognize the role that the Commission plays with respect to our nation's spectrum. Our first duty is to ensure that this valuable resource is used as efficiently as possible without causing harmful interference to important applications, such as GPS, deployed in the adjacent RNSS band. The extensive record associated with this proceeding informs our

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<sup>444</sup> Ligado shall submit its reports to the FCC by filing it as a "non-docketed pleading" using the International Bureau Filing System, available at <http://licensing.fcc.gov/myibfs/pleading.do>. Ligado shall reference IBFS File Numbers SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, SAT-AMD-20180531-00044, SAT-AMD-20180531-00045, and SES-AMD-20180531-00856. Ligado shall contact the FAA to determine its preferred filing procedure for these reports.

action. With respect to certified aviation receivers, commercial cellular, general location and navigation, general non-certified aviation, high-precision receivers, and MSS operations, we conclude that harmful interference concerns relating to GPS are effectively resolved based on the parameters of Ligado's amended modification applications, the test data/analyses presented in the record, and the conditions imposed in this Order and Authorization, which address any identified potential harmful interference concerns before ATC network operations commence.

158. Ligado negotiated with the GPS industry and other key stakeholders to reach private agreements to address harmful interference concerns and modified its ATC authority applications to reflect key terms of those agreements. Major companies in the GPS industry, working with Ligado, have taken actions to improve the performance of GPS and GPS/GNSS devices to ensure they can co-exist with and tolerate not only the types of power levels contemplated in this Order and Authorization but also the many other sources of RF interference that could be encountered in the L-band spectrum. These improvements to GPS components and devices are meaningful and important, and indeed are critical to ensuring that GPS-enabled devices (including those operating with Galileo GNSS signals) can co-exist with the transmitter power levels that are currently permitted in the RF environment adjacent to or near the RNSS allocation and are more resilient and robust. Through these improvements and the conditions adopted today, we address harmful interference concerns for adjacent band operations. Our decision to allow Ligado to conditionally use its ATC authority in its L-Band spectrum is in the public interest because it helps fulfill our spectrum management responsibilities, furthers our commitment to bringing advanced communications services to the public, and unleashes more spectrum for new service offerings that will benefit American consumers and businesses.

## **V. ORDERING CLAUSES**

159. Accordingly, IT IS ORDERED, pursuant to Section 309 of the Communications Act, 47 U.S.C. § 309, that Application File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091 ARE GRANTED IN PART AND DENIED IN PART, and Ligado Networks Subsidiary LLC's authorization for Ancillary Terrestrial Component operations (Call Signs: E980179, AMSC-1, and S2358) is modified to include authority to provide terrestrial service as described in its application, and subject to the conditions specified in paragraphs 131-155 of this Order and Authorization.

160. IT IS FURTHER ORDERED that this authorization is subject to the representations and limiting specifications in the application for modification; the previously-established terms and conditions for operation of Ligado satellites and associated ATC facilities, except as modified herein; and the Commission's applicable rules and regulations, except as explicitly waived herein.

161. IT IS FURTHER ORDERED that a partial waiver of the integrated service requirement, 47 C.F.R. § 25.149(b)(4), IS GRANTED to Ligado, subject to the conditions specified in paragraphs 131-155 of this Order and Authorization.

162. IT IS FURTHER ORDERED that with the exception of the report required in paragraph 155, above, to be filed in the International Bureau Filing System, the reports required in paragraphs 148 and 151-155, above, must be filed with the Commission's Secretary, referencing SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00090, and copies must be sent by email to IB-SATFO@fcc.gov.

163. IT IS FURTHER ORDERED that two copies of this Order and Authorization be submitted to the Committee on Energy and Commerce and the Committee on Armed Services of the House of Representatives and the Committee on Commerce, Science, and Transportation and the Committee on Armed Services of the U.S. Senate, and that Ligado cannot commence commercial ATC operations earlier than 90 days from the release of this Order and Authorization.

164. IT IS FURTHER ORDERED that this Order and Authorization is effective upon release. Petitions for reconsideration under 47 C.F.R. § 1.106 may be filed within thirty days of the release date. See 47 C.F.R. § 1.4(b)(2).

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch  
Secretary



**STATEMENT OF  
COMMISSIONER BRENDAN CARR**

Re: *LightSquared Technical Working Group Report*, IB Docket No. 11-109; *LightSquared License Modification Application*, IBFS File 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, SAT-MOD-20151231-00091, IB Docket Nos. 11-109, 12-340; *Ligado Amendment to License Modification Applications*, IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, IB Docket No. 11-109.

America's economic and national security depend on the private sector building the strongest 5G platform in the world right here in the U.S. And since the start of 2017, we have executed on a concrete plan to achieve that goal. We have modernized infrastructure rules so that the private sector can build 5G networks at an accelerated clip. And we have freed up the large swaths of spectrum needed to power next-gen applications. Today's decision builds on the unmistakable momentum America now has for 5G.

After a thorough and multi-year review, the FCC's professional staff of engineers and other experts determined that we can advance America's 5G leadership while protecting GPS and other adjacent band services. I welcome and support their determination. At the same time, this is not a decision that anyone at the FCC took lightly. Government and private sector stakeholders alike expressed earnest and differing views on the merits of Ligado's proposal. Perhaps that is why FCC leadership passed on reaching a final decision in this proceeding for so long. From Chairman to Chairwoman to Chairman to Chairman, when agency leadership turned over, they would hand their successor two things: the gavel and the Ligado proceeding. I am pleased that Chairman Pai showed the leadership to bring a final decision forward for a vote.

To gain the FCC's approval, Ligado made significant modifications to its original proposal, including greatly reduced power levels, the addition of new guard bands to protect and provide even more spectrum separation to adjacent services, and reaching co-existence agreements with manufacturers of high-precision GPS receivers. Our decision today also includes extensive additional protections to adjacent band operations, including requirements for Ligado to perform drive tests and 24/7 monitoring of transmit power levels, among other detailed protection mechanisms. These firm commitments coupled with the FCC's detailed review of numerous technical studies enabled our engineers to recommend that the Commission allow the private sector to put this spectrum to a higher and more productive use.

The public interest benefits in proceeding today are borne out by the broad and bipartisan support we now see—from Attorney General Bill Barr to Secretary of State Mike Pompeo, from Senator Ron Johnson to Senator Mark Warner, from Representative Billy Long to Representative Doris Matsui. In fact, studies show that allowing the private sector to combine this mid-band spectrum with other airwaves already targeted for 5G builds will produce a more robust and cost-effective network in the U.S. That is a good win for the country, and it is one that will further extend America's leadership in 5G, IoT, and other next-gen applications.

**JOINT STATEMENT OF  
COMMISSIONERS JESSICA ROSENWORCEL AND GEOFFREY STARKS,  
CONCURRING**

Re: *LightSquared Technical Working Group Report*, IB Docket No. 11-109; *LightSquared License Modification Application*, IBFS File 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, SAT-MOD-20151231-00091, IB Docket Nos. 11-109, 12-340; *Ligado Amendment to License Modification Applications*, IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, IB Docket No. 11-109.

This decision was an extremely close call. While many stakeholders now back the ancillary terrestrial service that is the subject of this order, others remain concerned about the potential for harmful interference. In the end we are compelled to support the expert technical analysis done by the Federal Communications Commission’s engineering staff. However, we choose to concur because this process has exposed a fault line in spectrum decision-making. You don’t have to take our word for it – House Energy and Commerce Committee Chairman Frank Pallone and Ranking Member Greg Walden jointly cited this matter as an example of “recent federal spectrum management process breakdowns.”<sup>1</sup> As we move to the next generation of wireless service, it is imperative that we have an improved inter-agency system and a stronger whole-of-government approach to our 5G effort.

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<sup>1</sup> Letter from Frank Pallone, Chairman and Greg Walden, Ranking Member, House Committee on Energy and Commerce, to the Honorable Gene L. Dodaro, Comptroller General of the U.S. (Jan. 24, 2020) (requesting “an updated review of the National Telecommunications and Information Administration’s (NTIA) federal spectrum management processes, how federal spectrum users interact with the NTIA and the [FCC, and] how the NTIA and FCC interact with each other”).