Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Spire Global, Inc.	)	IBFS File No. SAT-MOD-_____
	)	
Application to Modify	)	
SAT-LOA-20151123-00078	)	
SAT-AMD-20180102-00001	)	
SAT-PDR-20190321-00018	)	

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MODIFICATION DESCRIPTION

Spire Global, Inc. ("Spire") asks the Federal Communications Commission ("FCC" or "Commission") to adopt the following modifications for the FCC authorizations permitting Spire's LEMUR and MINAS non-geostationary satellite orbit ("NGSO") Earth Exploration-Satellite Service ("EESS") and Meteorological-Satellite Service ("MetSat") operations.[1]

- Amend Market Access Grant Condition 4 and License to permit 175 combined operational LEMUR and MINAS satellites, irrespective of their classification as Phase IC or Phase II satellites, to downlink data in 2020-2025 MHz on a non-interference, non-protected basis;
- Amend License Condition 15 and Market Access Grant to allow 175 combined operational LEMUR and MINAS satellites, irrespective of their Phase classification, to operate in 402-403 MHz until November 22, 2029 instead of the current October 31, 2020 phase-out deadline;

[1] *See generally* Stamp Grant, Spire, IBFS File No. SAT-PDR-20190321-00018 (granted in part Oct. 7, 2019) ("Market Access Grant"); Stamp Grant, Spire, IBFS File No. SAT-AMD-20180102-00001 (granted in part Nov. 29, 2018) ("License"). Attached to this application is a comprehensive Schedule S that includes all of these changes.

- Grant 175 combined operational Phase II LEMUR and MINAS satellites authority to employ space-to-space, or inter-satellite ("ISL") links, in the frequency bands 2025-2110 MHz and 2200-2290 MHz;
- Approve 175 combined operational LEMUR and MINAS satellites, irrespective of their classification, to passively measure the bend or refraction—and not the content—of foreign Global Navigation Satellite System ("GNSS") signals for non-on-orbit-determination operations, such as radio occultation ("RO") and reflectometry ("R") for meteorological and land surface monitoring purposes only;
- Amend the Scope of the Grant section and footnote 2 in the License and Market Access Grant to authorize operational LEMUR and MINAS satellites, each weighing 6 kg instead of 4.5 kg; and
- License the KeyW Corp. ("KeyW") hosted payload ("KeyW Payload") operating in the frequency bands 8025-8325 MHz (space-to-Earth) and 9200 MHz-10550 MHz (Earth-to-space) on one authorized Phase II LEMUR satellite bus.[2]

Spire certifies there are no other modifications to its LEMUR and MINAS systems[3] and incorporates by reference all pertinent waiver requests from its previously submitted satellite

[2] Spire and KeyW submitted separate experimental license applications July 2019. *See* Experimental License Application of KeyW, ELS File No. 1403-EX-ST-2019 (filed July 31, 2019) ("KeyW Payload STA Application"); Experimental License Application of Spire, ELS File No. 1228-EX-ST-2019 (filed July 3, 2019); *see also* Grant, KeyW, ELS File No. 1403-EX-ST-2019 (granted Jan. 8, 2020) ("KeyW Payload STA"). However, the IB recently asked Spire to file this request as one Part 25 license modification. As requested, Spire now seeks authority for the KeyW Payload to operate on board one of its authorized 236 authorized Phase II LEMUR satellites and asks the Commission to place the KeyW Payload portion of this application request on public notice, separate from the other requests, as soon as feasible. Such processing will enable Spire and KeyW to comply with forthcoming launch-related deadlines.

[3] The total number of authorized satellites for the 15-year license term will remain at 872.

license and market access applications.[4] As detailed below, grant of this modification application serves the public interest.

The Commission has authorized Spire to construct, deploy, and operate: (i) 28 technically identical Phase IA satellites, initially deployed to orbital altitudes of no greater than 650 km;[5] (ii) 28 technically identical Phase IB satellites, initially deployed to circular orbits of no greater than 500 km in altitude;[6] and (iii) 72 Phase IC satellites, initially deployed to circular orbits of no greater than 600 km in altitude.[7] Spire has also received authority to deploy 872 Phase II satellites: 236 U.S.-licensed LEMUR and 636 Luxembourg-licensed MINAS satellites, initially deployed to altitudes from 385 to 650 km in inclinations ranging from equatorial to polar sun-synchronous (98 degrees).[8] No more than 175 combined LEMUR and MINAS satellites, however, may simultaneously operate on orbit.[9] Today, Spire operates 88 LEMUR and MINAS satellites on orbit.

I. 2020-2025 MHz OPERATIONS FOR PHASE IC AND PHASE II SATELLITES

Spire requests the Commission amend the Market Access Grant condition 4 and the License to permit (i) 175 combined LEMUR and MINAS Phase IC and Phase II satellites to

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[4] *See* Application of Spire, IBFS File No. SAT-LOA-20151123-00078, Narrative at 18-24 (filed Nov. 23, 2015); Application of Spire, IBFS File No. SAT-PDR-20190321-00018, Narrative at 13-17 (filed Mar. 21, 2019). Attachment 2 (Updated Ownership Exhibit) attached hereto reflects changes in the disclosable shareholders, directors, and officers of Spire.

[5] *See* Stamp Grant, Spire, IBFS File No. SAT-LOA-20151123-00078 (granted in part Mar. 18, 2016); Stamp Grant, Spire, IBFS File No. SAT-LOA-20151 123-00078 (granted in part June 16, 2016); Stamp Grant, Spire, IBFS File No. SAT-LOA-20151123-0007 (granted in part Oct. 14, 2016). Spire has deployed all 28 of its Phase IA satellites.

[6] *See* Stamp Grant, Spire, IBFS File No. SAT-AMD-20161114-00107 (granted in part Apr. 7, 2017); Stamp Grant, Spire, IBFS File No. SAT-AMD-20161114-00107 (granted in part May 18, 2017). Spire has deployed all 28 of its Phase IB satellites.

[7] *See* Stamp Grant, Spire, IBFS File No. SAT-AMD-20161114-00107 (granted in part July 13, 2017). Spire has deployed 34 of its Phase IC satellites.

[8] *See* Market Access Grant; License.

[9] *See* Market Access Grant at Condition 3.

downlink data in 2020-2025 MHz on a non-interference, non-protected basis. Currently, Spire may only deploy "as many satellites as will limit to 72 the combined number of LEMUR and MINAS satellites that have operated, operate, and will operate with U.S. earth stations."[10] After discussions with the FCC International Bureau ("IB"), Satellite Division, Spire understands this condition permits only 72 combined LEMUR and MINAS Phase IC satellites to operate in 2020-2025 MHz. Considering Phase II satellites will operate on orbit simultaneously with the Phase IC satellites in this band, Spire requests modified authority to concurrently operate 175 combined LEMUR and MINAS satellites, irrespective of their class, in this band on a non-interference, non-protected basis. Permitting such operations will serve the public interest because Spire will put this otherwise unused spectrum to valuable use. If, however, fixed or mobile operators commence operations in this band during Spire's License and Market Access Grant term, Spire will proactively coordinate with the operators to evaluate potential interference concerns and modify its already intermittent operations to mitigate concerns.

II. 402-403 MHZ OPERATIONS UNTIL NOVEMBER 22, 2029

Condition 15 in the License prohibits Spire from using 402-403 MHz after October 31, 2020, but good cause exists for the FCC to amend this License condition and the Market Access Grant and permit Spire to operate in the band until November 22, 2029.[11] The International Telecommunication Union World Radiocommunication Conference ("WRC")-19 decided that TT&C operators, which have brought into use and notified their systems prior to November 22, 2019 ("WRC-19 Filing Deadline"), may operate in 402-403 MHz with no EIRP limits until November 22, 2029. Spire brought into use the LEMUR system on May 5, 2017 and MINAS system on December 27, 2018 and submitted its notification for the LEMUR system on

[10] *See* Market Access Grant at Condition 4.
[11] *See* License at Condition 15.

September 25, 2019 and MINAS system on September 24, 2019.[12] These filing dates predate the WRC-19 Filing Deadline. Therefore, accommodating this request would mirror the International Telecommunication Union ("ITU") WRC-19 outcome the United States Administration negotiated and supported at WRC-19. To mitigate any additional concerns, however, Spire continues to coordinate its transition out of this frequency band with the interested Federal agencies.

III. INTER-SATELLITE LINKS IN 2025-2110 MHZ AND 2200-2290 MHZ

Spire's constellation maps out and reports on rapidly changing phenomena on Earth. A crucial part of this operation is the timeliness (or latency) of the data. Continuing with a store-and-forward concept of operations may not address the future market demands for such low-latency data services. As a result, Spire plans to deploy radiofrequency ISLs to provide a low-latency, low-power, low-data-rate route for the highest priority tiers of data to get to the end user faster.

Spire now requests to operate ISLs in two 1-megahertz segments of bandwidth in the 2025-2110 MHz allocation and two 1-megahertz segments of bandwidth in the 2200-2290 MHz allocation for 175 combined Phase II LEMUR and MINAS satellites. It has initially proposed to use the 2025-2026 MHz, 2109-2110 MHz, 2200-2201 MHz, and 2289-2290 MHz channels but will finalize the selection only after completing coordination with the co-frequency U.S. Federal operators.

Good cause exists to permit Spire's 2025-2110 MHz and 2200-2290 MHz ISL operations. In both bands, the Table of Frequency Allocations authorizes Space Operations and

[12] *See* ITU Notification of LEMUR-2-3 NGSO System, Submission Reference USA2019-21204, Notice ID 119500244 (filed Sept. 25, 2019), https://bit.ly/2XvGUWr; ITU Notification of MINAS NGSO System, Submission Reference LUX2019-21227, Notice ID 119500236 (filed Sept. 24, 2019), https://bit.ly/2zxr3i2.

EESS space-to-space operators on a primary basis in all three ITU regions.[13] In the United States Table of Frequency Allocations, footnote US347 further permits non-Federal space-to-space operations for EESS operations in the 2025-2110 MHz band on a case-by-case basis. Spire's proposed operations qualify as EESS because it will be transmitting and receiving data related to the Earth's atmospheric and land surface properties. Therefore, its ISL operations in 2025-2110 MHz conform to the U.S. Table of Frequency Allocations. As detailed below, a non-Federal space-to-space allocation does not exist in the 2200-2290 MHz band, so Spire requests a waiver of the U.S. Table of Frequency Allocations for its non-conforming use.[14]

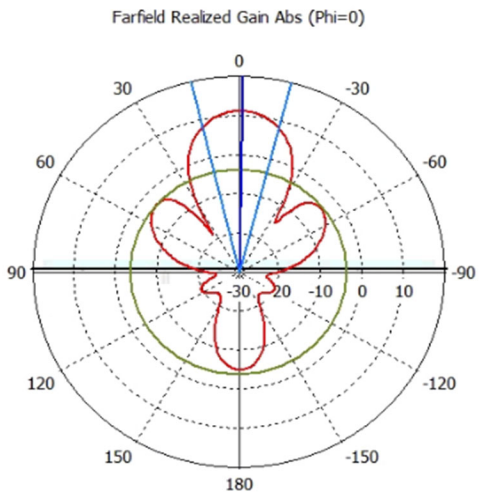
A. Technical Parameters

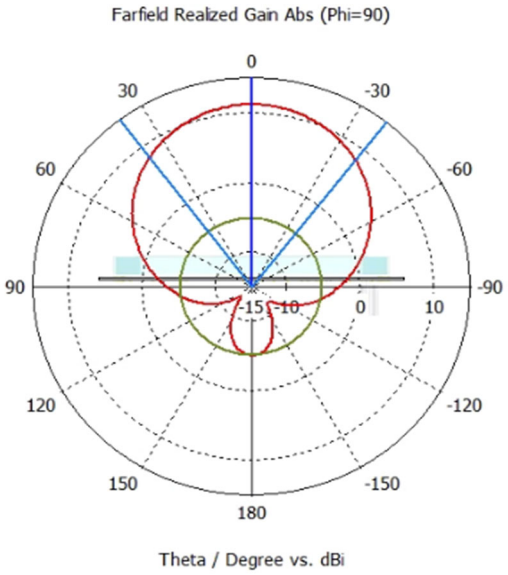
Assuming an in-plane, leader-follower configuration with an assumed range between the satellites of 1000-2000 km, Spire's ISLs in 2025-2110 MHz (two one-megahertz channels) and 2200-2290 MHz (two one-megahertz channels) will possess the following characteristics.

- Beam type: Fixed
- Polarization: RHCP
- 3 dB gain: 2025-2110 MHz (8.3 dBi) and 2200-2290 MHz (8.6 dBi)
- Max transmit EIRP: 2025-2110 MHz (7.27 dBW) and 2200-2290 MHz (7.93 dBW)
- Beamwidth: vertical plane 25º (±12.5º), horizontal plane 60º (±30º)
- Bandwidth: 1 MHz
- Emission type: 1M00M1D
- Coding: QPSK DVB-S2 ¼
- Data rate: 70-300 kb/s
- Duty cycle: two 10-15 minute windows in a 90-minute orbit

The radiation patterns for the ISL antennas appear below.

[13] *See* 47 C.F.R. § 2.106 (U.S. Table of Frequency Allocations).
[14] *See infra* Part VII.





B. Power Flux Density ("PFD") Limit Compliance

Section 25.208 of the FCC's rules includes no PFD limits for the 2025-2110 MHz and 2200-2290 MHz bands; however, ITU Radio Regulations Table 21-4 contains PFD limits for space-to-space operations in these bands.[15] Table 21-4 states that the PFD at the Earth's surface produced by an EESS space station's emissions in these frequency bands for all conditions and modulation methods shall not exceed the following values:

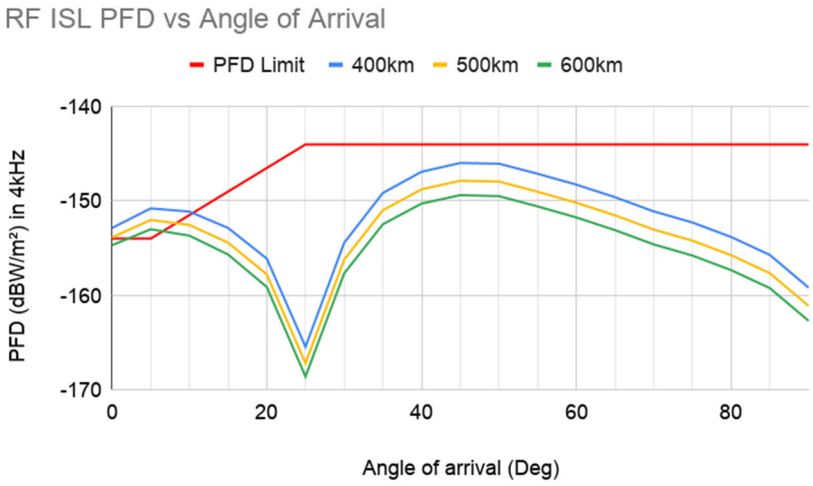
[15] *See* 47 C.F.R. § 25.208; ITU Radio Regulations Table 21-4 ("ITU Table 21-4").

- -154 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -154 + 0.5(d-5) dB(W/m^2) in any 4 kHz band for angles of arrival d (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -144 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.[16]

Spire calculated the PFD as follows:

> PFD [dBW/m^2/4 kHz] = EIRP (dBW) – 11 – 20log10(D) – 10log10(BW) + 36
>
> where EIRP is the Maximum EIRP of the transmission, D is the distance between the satellite and affected surface area in km, and BW is the bandwidth of the transmission in MHz.

The calculations establish that Spire can comply with the applicable limits at all angles of arrival except 0-10 degrees. At these non-compliant angles, Spire will terminate operations to avoid interference concerns.



C. Protecting Deep-Space Research Earth Station Operations

ITU-R Recommendation SA-1157 specifies a maximum allowable interference power spectral flux-density level at the Earth's surface of -222 dB(W/Hz) to protect ground receivers in the deep-space research band operating in the 2290-2300 MHz frequencies.[17] Any Spire 2289-

[16] *See* ITU Table 21-4.
[17] *See* Recommendation ITU-R SA.1157-1 (2006) (deep-space research protection criteria).

2290 MHz transmissions—at their worst angle of arrival directly above a receiving deep space earth station—into the 2290-2300 MHz band will possess a maximum interference power spectral density of -232.74 dB(W/Hz). This value complies with the -222 dB(W/Hz) limit.[18] To assuage any remaining interference concerns, the company will implement baseband digital and hardware radiofrequency filtering and consider using transmit channels smaller than one megahertz.

D. Protecting Other Satellite Operations

In the absence of applicable ITU and U.S. requirements protecting NGSO and geostationary satellite orbit satellites in the 2025-2110 MHz or 2200-2290 MHz bands from ISL interference, Spire will implement modulation and channel coding techniques to reduce interference concerns. The Space Frequency Coordination Group ("SFCG"), which includes the U.S. Federal agencies, has recommended that NGSO operators reduce their ISLs' power spectral density by "using appropriate modulation techniques and channel coding in accordance with [Consultative Committee for Space Data Systems ("CCSDS")] recommendations."[19] Spire will incorporate QPSK DVB-S2 ¼ coding and consider implementing other CCSDS techniques to reduce the system's power spectral density and protect other co-channel satellites operating in

[18] *See id.*

[19] *See, e.g.*, *Interference from Space-to-Space Links between Non-geostationary Satellites to Other Space Systems in the 2025-2110 and 2200-2290 MHz Bands*, SFCG (Oct. 20, 2005), https://bit.ly/38UT26J. CCSDS recommendations provide technology-agnostic guidance by generally noting that the specific ISL architecture requirements and mitigation techniques will vary by mission and its link characteristics. *See, e.g.*, *Space Communications Cross Support – Architecture Requirements Document*, CCSDS § 6 (May 2015), https://bit.ly/2INYVIw ("This section does not attempt to provide concrete guidance for the selection of specific modulation, coding, or link layer standards for any particular application. That is a deep technical subject that requires careful analysis of mission and communications asset characteristics and mission trajectory.").

these bands. The company, also as mentioned, will engage with the Federal operators to coordinate its proposed ISL use in these bands.

IV. PASSIVE MONITORING OF FOREIGN GNSS SIGNALS

Spire seeks authority to measure the refraction, reflection, and other distortion of signals, readily accessible to the general public, through its space station receivers for the purpose of inferring atmospheric and Earth surface[20] properties.[21]

Title 18 of the United States Code permits any persons to access an (i) "electronic communication made through an electronic communication system that is configured so that such electronic communication is readily accessible to the general public"[22] or (ii) encrypted signal as long as it is not decrypted or decoded.[23] Although there are no explicit Commission rules preventing Spire from measuring readily accessible signals through the use of space station receivers,[24] the Commission may deny requested authorizations if they may cause potential foreign policy and national security concerns.[25]

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[20] Potential applications could include soil moisture and vegetation sensing, snow depth monitoring, sea ice mapping, etc.
[21] Spire will not read the content of these signals.
[22] 18 U.S.C. § 2511(2)(g)(i).
[23] *See id.* § 2510(16) ("[R]eadily accessible to the general public" means, with respect to a radio communication, that such communication is not— (A) scrambled or encrypted; (B) transmitted using modulation techniques whose essential parameters have been withheld from the public with the intention of preserving the privacy of such communication; (C) carried on a subcarrier or other signal subsidiary to a radio transmission; (D) transmitted over a communication system provided by a common carrier, unless the communication is a tone only paging system communication; or (E) transmitted on frequencies allocated under part 25, subpart D, E, or F of part 74, or part 94 of the Rules of the Federal Communications Commission, unless, in the case of a communication transmitted on a frequency allocated under part 74 that is not exclusively allocated to broadcast auxiliary services, the communication is a two-way voice communication by radio.").
[24] *See generally* 47 C.F.R. Part 25.
[25] *See* 47 C.F.R. § 25.156(a) (stating that applications for a radio station authorization will only be granted if the Commission finds that it will "serve the public interest, convenience and necessity").

The foreign policy and national security concerns—possible spoofing of GNSS signals leading to faulty Earth observation data generation—are not implicated by Spire's requested authority. There are waveform modulations being constantly emitted through the Earth's atmosphere in the 1164-1300 MHz and 1559-1610 MHz frequency bands. With the correct equipment, any person can detect, passively monitor, measure, and/or read the content of the waveform modulations of signals in these frequency bands. Spire, however, will only measure these waveform modulations' refraction, reflection, or other distortion for the purpose of inferring atmospheric and Earth surface properties, and it will not use these waveform modulations for the provision of any safety or position, navigation, or timing services or determining Spire satellites' on-orbit location.[26] Spire will not attempt, nor has the capability, to decode or decrypt any encrypted content within these waveform modulations. Additionally, Spire's measuring of these readily accessible signals' refracted, reflected, or distorted waveform modulations will not cause interference to other users nor will it result in compensation to the parties generating the readily accessible waveform modulations.

A. Foreign GNSS Satellite Position Determination

While all foreign GNSS systems broadcast their orbital positions in their satellite signals, Spire does not use the foreign GNSS systems' broadcast positions at all. Instead, Spire uses foreign GNSS satellite positions that are determined by the International GNSS ("IGS") network of ground stations unrelated to any one foreign GNSS system.[27] IGS is a voluntary federation of over 200 self-funding agencies, universities, and research institutions in more than 100 countries working together to provide the highest precision and "highest-quality GNSS data, products and

[26] Spire will only rely on Global Positioning System ("GPS") signals for determining the position of its own satellites.
[27] *See generally About*, IGS, http://www.igs.org/about (last viewed May 26, 2020).

services in support of the terrestrial reference frame, Earth observation and research; positioning, navigation and timing; and other applications that benefit science and society."[28] Spire uses a third-party provider which independently verifies the IGS-provided GNSS satellite positions.

There are no known cases of spoofing of GNSS signals for purposes of degrading GNSS-based Earth observations. In fact, most known cases of spoofing are against U.S. GPS satellites for purposes of degrading U.S. navigation capabilities in time of war.[29] A country spoofing its own GNSS signals would throw off its own navigational capabilities now and in time of war. Use of GNSS signals from multiple constellations provides a diversity of signals for Spire to use to minimize spoofing concerns, actually reducing any risk to Earth observation capabilities. For example, the math of GNSS-RO, which is referenced below, is so complex that spoofing signals would produce such low-fidelity information that it would be filtered out before it ever reached a weather forecasting model.

As noted previously,[30] Spire will not use foreign GNSS signals to determine the on-orbit location of the Spire satellites. It will only use U.S. GPS signals for that purpose.

B. GNSS Data Assimilation Process

Profiles are verified through Spire's quality control program, which performs many detailed checks (three of which are highlighted below).

1) Quality control of the RO data is based on a dimensionless quality metric, penetration depth, and bending angle noise. The dimensionless quality metric is an empirical measure of the data quality evaluated at the level of RO data processing from excess phase to the refractivity

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[28] *Id.*

[29] *See, e.g.*, David Hambling, *Ships fooled in GPS spoofing attack suggest Russian cyberweapon*, New Scientist (Aug. 10, 2017), https://www.newscientist.com/article/2143499-ships-fooled-in-gps-spoofing-attack-suggest-russian-cyberweapon/.

[30] *See supra* Part IV; *see also, e.g.*, Application of Spire, IBFS File No. SAT-PDR-20190321-00018, Exhibit B at 7-8 (filed Mar. 21, 2019).

profile. Profiles with a poor quality metric are discarded before their assimilation into the forecast processing system in step 2.

2) A weather forecasting team will look at consistency between data points (all remaining profiles as well as tens of millions of other inputs (*i.e.*, microwave soundings, weather balloons, etc.)) and weight data points based on consistency, giving little or no weight to inconsistent data, including profiles. Those outliers (*i.e.*, bad data) are thrown out and not used to run a forecast.

3) All forecast models are then compared with other forecast models to make sure they are of high fidelity. There are standard scoring methods, which are widely accepted in the weather community, for how good a model is.

V. DEPLOYING 6 KG SATELLITES INSTEAD OF 4.5 KG SATELLITES

As Spire's experience and technology have advanced, it has optimized the use of the volume inside a 3U cubesat. This optimization has resulted in an increased mass of the satellite greater than the nominal mass when the original application was submitted. With all of Spire's data collection payloads installed, the satellite has a mass approaching 6 kg.

This upper limit mass was envisioned and discussed in its previously submitted Orbital Debris Assessment Report ("ODAR"). This report shows that even up to 6 kg, Spire meets the Commission's deorbit, collision, and human casualty risk requirements.[31]

[31] *See* Application of Spire, IBFS File No. SAT-AMD-20180102-00001, Exhibit B (Orbital Debris Risk Mitigation Plan) and Exhibit C (ODAR) (filed January 2, 2018). Attachment 2 (Updated Ownership Exhibit) attached hereto reflects changes in the disclosable shareholders, directors, and officers of Spire.
instant application, evidence Spire's compliance and demonstrate how Spire will maintain a safe and sustainable orbital environment.

Spire understands that it must receive Commission approval of a revised Spire orbital debris risk mitigation plan and ODAR before deploying over 100 satellites on orbit.[32] It will submit these materials shortly.[33]

VI. KEYW HOSTED PAYLOAD INFORMATION

Spire also seeks to modify its License[34] to operate one KeyW Payload in segments of the 8025-8325 MHz band (space-to-Earth) and 9200-10550 MHz band (Earth-to-space) on one of its authorized Phase II LEMUR spacecraft pursuant to an agreement with KeyW.[35] The KeyW Payload will obtain valuable information regarding antenna performance and pointing control to facilitate the development of novel intelligence, surveillance, and reconnaissance ("ISR") technologies for use by U.S. government entities for critical homeland security and defense missions.[36] The proposed operation of the KeyW Payload would be consistent with applicable Commission rules, regulations, and policies; and would serve the public interest, convenience, and necessity.[37]

A. Discussion

Spire proposes to conduct satellite transmit (downlink) operations in the 8025-8325 MHz band and satellite receive (uplink) operations in the 9200-10550 MHz band. Satellite transmit

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[32] *See* License at Condition 4; Market Access Grant at Condition 5.
[33] *See id.* This information will include the aggregate collision risk for the Spire system at all altitudes requested based on launches completed and planned. If the Commission does not approve of the revised package before the 101st satellite deployment, then Spire will decrease the number of MINAS satellites communicating with U.S. earth stations to ensure the total number of LEMUR satellites communicating with U.S. earth stations does not surpass 100.
[34] *See* 47 C.F.R. §§ 25.114, 25.117.
[35] The Spire Phase II LEMUR satellite hosting the KeyW Payload will possess physical dimensions and a mass no greater than a nominal Spire Phase II satellite. *See* Exhibits B and C. This satellite will comply with the Commission's orbital debris requirements. *See id.*
[36] Spire hereby incorporates by reference into this modification application the information associated with the KeyW Payload STA intended to support KeyW Payload operations. *See* KeyW Payload STA Application.
[37] *See* 47 C.F.R. §§ 25.114, 25.117.

operations in the 8025-8325 MHz band are already included in the Spire License but are included in this modification application because the KeyW Payload will use a different antenna and will communicate with a U.S. earth station different than those authorized for Spire. Satellite receive operations in the 9200-10550 MHz band are non-interfering and, as a non-conforming user of spectrum, Spire agrees to accept all interference from conforming operations in the band. The use of frequencies as proposed herein has already been coordinated and approved by the Commission under the KeyW Payload STA.[38]

1. Satellite Transmit (Downlink) Operations in the 8025-8325 MHz Band

The 8025-8325 MHz band has various Federal allocations and is also allocated for Earth EESS use.[39] The proposed downlink operations would be similar to EESS downlink transmissions, particularly since they would be intermittent and directed towards a single earth station site in the southwestern United States. Nonetheless, Spire's proposed satellite transmit operations would be on a non-conforming (unprotected, non-interference) basis and, therefore, has no regulatory status vis-à-vis other authorized users of the band. Spire will not claim protection from authorized operations and will otherwise ensure compatibility with U.S. government and commercial operations.

KeyW Payload downlink transmissions will be conducted in two modes: communications mode (using a traditional modulating carrier (QPSK)) and "chirp" mode (*i.e.,* a swept gaussian modulated sinusoidal waveform)). Spire has included a representative link budget (appended as Attachment 3). The KeyW Payload will operate intermittently and on an as-needed basis to

[38] Spire hereby incorporates the information included in the KeyW Payload STA Application by reference into this modification application.
[39] *See* 47 C.F.R. § 2.106, n.US258.

conduct transmit antenna testing and demonstration during approximately one pass per day (approximately 6-8 minutes per pass) to an earth station located in Tucson, Arizona.[40]

Spire has entered into a coordination agreement with National Aeronautics and Space Administration ("NASA") (representing itself and other U.S. government agencies) covering downlink frequencies including the 8025-8325 MHz band. Spire is engaged with NASA to ensure that the proposed operation of the KeyW Payload with a single earth station located in Tucson, Arizona is included in the coordination agreement. Spire will operate the KeyW Payload in accordance with the provisions of its coordination agreement with NASA, including any additional conditions on KeyW Payload operations.

2. Satellite Receive (Uplink) Operations in the 9200-10550 MHz Band

The 9200-10550 MHz band has various allocations for both Federal and non-Federal uses, including a secondary allocation for radiolocation operations.[41] Spire's proposed satellite receive operations would be on a non-conforming (unprotected, non-interference) basis and, therefore, has no regulatory status vis-à-vis other authorized users of the band. Spire will not claim protection from authorized operations and will otherwise ensure compatibility with U.S. government and commercial operations.

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[40] Spire understands that, subject to separate Commission authority, KeyW or a partner will operate a 1.5-meter tracking earth station antenna located at a University of Arizona facility in Tucson, Arizona to communicate with the KeyW Payload. Such operations will not cause interference to U.S. government or commercial facilities in the southwestern United States. The earth station will track the Spire satellite as it passes over the site and will transmit in the 9200-10550 MHz band for brief periods but will not operate below a minimum elevation angle of 10 degrees (or such other minimum elevation angle at azimuth as agreed with U.S. government representatives). There are two non-Federal FCC-licensed operators in the 9200-10550 MHz band within a 50-mile radius of the earth station site, Trimble Inc. and Airobotics Inc., which have been contacted and have expressed no concerns regarding the proposed operations. *See* KeyW Payload STA Application, Narrative at 3-5.

[41] *See* 47 C.F.R. § 2.106, nn.5.475B, 5.476A, 5.479, US108, US128, and NG50.

Spire has included a representative link budget (appended as Attachment 4). Low earth station transmit power (32 dBm or 1.58 W) results in a power received by the satellite of -86.85 dBm. Such low-power operations with a directional antenna, along with appropriate coordination, will ensure there is a *de minimis* potential for interference associated with the proposed operations. Furthermore, because the proposed operations will facilitate the development of innovative antenna technology for the benefit of the U.S. public,[42] grant of this modification will serve the public interest.

VII. WAIVER REQUESTS

The FCC may waive any of its rules if there is "good cause" to do so.[43] Generally, waiver is appropriate if (1) special circumstances warrant a deviation from the general rule; and (2) such deviation would better serve the public interest than would strict adherence to the rule.[44] The FCC will grant a waiver of its rules in a particular case if the relief requested would not undermine the policy objective of the rule in question and would otherwise serve the public interest.[45] Spire submits that good cause exists to waive the following rules.

A. U.S. Table of Frequency Allocations

As discussed, the U.S. Table of Frequency Allocations omits non-Federal allocations that would permit Spire LEMUR and MINAS satellites to use space-to-space links in the 2200-2290 MHz band, the KeyW Payload transmitter in the 8025-8325 MHz (space-to-Earth) band, and KeyW Payload receiver in the 9200-10550 MHz (Earth-to-space) band. As a result, Spire

[42] *See* KeyW Payload STA Application (including Confidential Exhibit 1 attached thereto).
[43] *See* 47 C.F.R. § 1.3; *Northeast Cellular Tel. Co. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).
[44] *See Northeast Cellular*, 897 F.2d at 1166.
[45] *See WAIT Radio*, 418 F.2d at 1157.

requests a waiver of U.S. Table of Allocations[46] to the extent necessary for the FCC to authorize the proposed operations.

In considering requests for non-conforming spectrum uses, the Commission has indicated that it would generally grant such waivers "when there is little potential for interference into any service authorized under the Table of Frequency Allocations and when the non-conforming operator accepts any interference from authorized services."[47] Compelling reasons exist to grant the requested waiver of the U.S. Table of Allocations in connection with this modification application.

1. 2200-2290 MHz (space-to-space for Spire satellite bus)

Because a non-Federal space-to-space allocation does not appear in the U.S. Table of Frequency Allocations for the 2200-2290 MHz band, Spire requests a waiver to use the band for its ISL operations.[48] ISL transmissions are inherently "international" as they may transit hundreds to thousands of kilometers in space and are not limited to the orbital area directly above the United States or its territories. Good cause exists for the FCC to waive the U.S. Table of Frequency Allocations.[49] All three ITU regions permit such "international" operations on a

[46] *See* 47 C.F.R. § 2.106.
[47] *Fugro-Chance, Inc.*, Order and Authorization, 10 FCC Rcd. 2860 ¶ 2 (IB 1995) (authorizing nonconforming MMSS in the C-band); *see also Motorola Satellite Communications, Inc.*, Order and Authorization, 11 FCC Rcd. 13952 ¶ 11 (IB 1996) (authorizing service to fixed terminals in bands allocated to the mobile satellite service); *Hughes Network Systems, LLC*, Declaratory Ruling, 26 FCC Rcd. 8521 ¶¶ 12-14, n. 1 (IB 2011); *Boeing Company*, Order and Authorization, 16 FCC Rcd. 5864 ¶¶ 8-9, 12 (IB and Office of Engineering and Technology 2001).
[48] *See id.*
[49] *See* 47 C.F.R. § 5.392 (informing NGSO ISL operators that they "shall not impose any constraints on Earth-to-space, space-to-Earth and other space-to-space transmissions of those services and in those bands between geostationary and non-geostationary satellites").

primary basis. Spire will comply with the applicable PFD and out-of-band emission limits and will coordinate this use with all Federal operators before beginning operations.[50]

2. 8025-8325 MHz (space-to-Earth for KeyW Payload)

As discussed above, the 8025-8325 MHz band is included in the Spire License and the transmission characteristics of the KeyW Payload are within the previously authorized operational envelope. Furthermore, Spire is engaged with NASA to ensure that operation of the KeyW Payload is incorporated into the coordination agreement to protect NASA and other U.S. government agency operations. Spire will operate the KeyW Payload in accordance with the provisions of this coordination agreement.

3. 9200-10550 MHz (Earth-to-space for KeyW Payload)

The proposed satellite receive operations in the 9200-10550 MHz band have no potential to cause interference to any service authorized under U.S. Table of Frequency Allocations. The associated low-power earth station uplink operations have been identified and coordinated with potentially affected parties to ensure they have no material impact on other spectrum users. Moreover, Spire will accept any interference from authorized services when conducting satellite receive operations in the 9200-10550 MHz band.

Given the foregoing, operation of the Spire satellite ISL frequencies and KeyW Payload will not cause harmful interference to other authorized users of the subject spectrum. For this reason, and because the proposed operations will facilitate testing of innovative antenna technologies that will benefit the U.S. government and the U.S. public, a waiver of Section 2.106 will strongly serve the public interest.[51]

[50] *See supra* Part III.
[51] *See* 47 C.F.R. § 2.106.

B. Modified Processing Round Rules

Spire requests waiver of Sections 25.156 and 25.157 of the FCC's rules, which require the processing of "NGSO-like satellite systems" under a modified processing round framework,[52] and incorporates by reference its previously submitted waiver request for the frequencies authorized for the Spire satellite bus.[53] As additional support for grant of the waiver request, Spire submits that the new ISL and KeyW Payload operations will not preclude future entrants from using the 2025-2110 MHz, 2200-2290 MHz, 8025-8325 MHz, and/or 9200-10550 MHz bands.

With respect to the Spire ISL operations in the 2025-2110 MHz band, the Commission has previously waived the modified processing round requirement and allowed EESS NGSO systems to be processed on a first-come, first-served basis and should do so here.[54] Spire's satellite system provides, *inter alia*, a meteorological and land surface monitoring service, both of which meet the definition of an EESS.[55] Data transferred through the ISLs will consist of the EESS and MetSat data the satellite bus payloads have procured. Spire's system is fully capable of sharing with current and future NGSO systems operating in the same frequency bands, and accordingly, there is no mutual exclusivity.[56] Because the purpose of the modified processing

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[52] *See* 47 C.F.R. §§ 25.156, 25.157.

[53] *See, e.g.*, Application of Spire, IBFS File No. SAT-LOA-20151123-00078, Narrative at 21-22 (filed Nov. 23, 2015).

[54] *See* Stamp Grant, Planet Labs, Inc., SAT-LOA-20130626-00087 (granted Dec. 3, 2013); Stamp Grant, Skybox Imaging, Inc., SAT-LOA-20120322-00058 (granted Sep. 20, 2012); Space Imaging, LLC, Declaratory Order and Order and Authorization, 20 FCC Rcd 11964 ¶¶ 9-11 (2005) ("*Space Imaging Order*").

[55] *See* 47 C.F.R. § 2.1 (defining MetSat as "[a]n earth exploration-satellite service for meteorological purposes"); *see also Space Imaging Order*, 20 FCC 11964 ¶ 1.

[56] Similar to its non-ISL operations, Spire ISL satellites will only transmit/receive when in line of sight of another Spire ISL satellite. Transmissions will occur for no more than two 10-15 minute windows in a 90-minute orbit, only when geometries are favorable, and not between satellites further than 2000 km from each other. *See supra* Part III.A. Spire satellites will also not track non-Spire ISL spacecraft, or victim satellites capable of potentially receiving interference. This

round is to preserve opportunities for competitive entry in frequency bands where licensing the first applicant to operate in the band would prevent subsequent applicants from using the spectrum, grant of the waiver would not undermine the rules.[57]

With respect to the Spire ISL operations in the 2200-2290 MHz band and KeyW Payload operations in the 8025-8325 MHz and 9200-10550 bands, authority is requested on a non-conforming (non-interference, non-protected) basis only, and this regulatory status would apply vis-à-vis subsequent co-frequency satellite applications. Given that the proposed operations cannot cause interference or receive regulatory protection, grant of authority to operate the Spire ISLs and KeyW payload in the requested frequency bands would not preclude any future satellite use of the band.

Accordingly, waiving Sections 25.156 and 25.157 will not undermine the policy objectives of these rules (to preserve opportunities for competitive entry in the same frequency bands) and will be in the public interest, and the grant of the waiver request is justified.

C. Default Service Rules

Spire requests a waiver of the default service rules[58] as applied to the ISL and KeyW Payload operations and incorporates by reference its prior waiver request.[59] The FCC has not adopted band-specific rules for the services to be provided by Spire ISLs or KeyW Payload or for the proposed use of the frequencies at issue. Because the proposed uses will not cause

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antenna pattern "sweep"-style operation and fact that co-frequency systems are not receiving all the time in this frequency band indicate that Spire's proposed operations are on a non-exclusive basis and that spectrum sharing remains possible.

[57] *See, e.g.*, *Space Imaging Order*, 20 FCC Rcd 11968 ¶ 10.

[58] *See* 47 C.F.R. § 25.217(b).

[59] *See, e.g.*, Application of Spire, IBFS File No. SAT-LOA-20151123-00078, Narrative at 22-23 (filed Nov. 23, 2015).

harmful interference or preclude other parties from using the same frequencies, as discussed above, grant of the waiver request is justified.

VIII. SPIRE SATELLITE BUS ITU ADVANCE PUBLICATION INFORMATION ("API")

Spire's non-ISL communications will operate under the U.S. "LEMUR-2-3" API. The company has modified this filing to accommodate its proposed ISL use and has simultaneously submitted it to the Commission with the instant application.

IX. KEYW HOSTED PAYLOAD ITU API

Spire has also submitted a separate ITU API for the KeyW Payload to the Commission, as IB requested.

CONCLUSION

For the foregoing reasons, Spire respectfully requests the Commission grant this modification request.

Respectfully submitted,

/s/ Ananda Martin
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SPIRE GLOBAL, INC.
251 Rhode Island Street
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June 3, 2020

Attachment 1 (Technical Certification)

I, Jeroen Cappaert, hereby certify, under penalty of perjury, that I am the technically qualified person responsible for the preparation of the engineering information contained in the technical portions of the foregoing application and the related attachments, that I am familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of my knowledge and belief.

/s/ Jeroen Cappaert
Jeroen Cappaert
Chief Technology Officer
Spire Global, Inc.
jeroen@spire.com

Attachment 2 (Updated Ownership Exhibit)

The following are shareholders with 10% or more of the equity and voting stock in Spire Global, Inc. ("Spire").

Peter Platzer	251 Rhode Island Street, Suite 204 San Francisco, CA 94104	USA: Austria	14.327%

The following individuals are directors of Spire:

Theresa Condor
Key Compton
Tess Hatch
Stephen Messer
Peter Platzer
Will Porteous

The following individuals are officers of Spire:

Peter Platzer (CEO, President)
Thomas Krywe (CFO)
Keith Spicher (Treasurer)
Ananda Martin (Secretary)
Jeroen Cappaert (Chief Technology Officer)

All of the directors and officers of Spire may be reached at the following address:

Spire Global, Inc.
251 Rhode Island Street
Suite 204
San Francisco, CA 94103

Attachment 3 (KeyW Payload Link Budget)

8025-8325 MHz (space-to-Earth)

Link Rate, bps	**2.50E+06**
System Parameters	
Frequency, Hz	8.20E+09
Wavelength, meters	0.0366
Symbol Rate, sps	2500000.00
Range, km	789.57
Modulation Description	QPSK
Modulation Order, {sqrt(M-ary states)}	2
FEC Code Rate, Rc	0.5
Interference Level, rel dB	-100.00
Elevation angle at max range, deg	12.22
Max PFD at NADIR, dBW/m^2/4 kHz	-142.98
Satellite Transmitter	
Gain, dBi	15.44
Depolarization Loss	0.00
Transmitter Power, dBm	23.00
Backoff, dB	0.00
Antenna Cable Loss, dB	0.00
Antenna Pointing Loss, dB	0.00
Scan Loss	0.00
EIRP, dBm	38.44
Gateway Receiver	
Antenna Temperature, K	50
Gain, dBi	39.63
Depolarization Loss	3.50
Receiver Line Losses	1.25
Receiver Noise Bandwidth, Hz	2.500E+06
Noise Figure, dB	2.40
Pointing loss, dB	0.50
Scan loss, dB	0.00
Net Receiver gain at antenna, dB	35.63
Noise Computations	
Boltzmann's Constant (k), J/K	1.38E-23
Line Loss Ratio	0.75
Ant temp	50.00
line temp ref to ant	96.72
Receiver Temp ref to ant	285.32
Background Noise	0.00
sys temp	432.04
Thermal Noise Power in Receiver, dBm	-108.27
Receiver G/T	9.77
Link	
EIRP, dBm	38.44
Space loss, dB	-168.66
Net Receiver gain at antenna port, dB	35.63
Power Received, dBm	-94.59
Interference Received, dBm	-194.59
Noise plus Interference Power, dBm	-108.27
Propagation Losses, dB	0.20
Carrier to Interference + Noise (CINR), dB	13.47
Implementaton Loss, dB	2.5
Eb/No, dB	10.97
Required Eb/No, dB	1.05
Margin, dB	**9.92**

Attachment 4 (KeyW Payload Link Budget)

9200-10550 MHz (Earth-to-space)

Link Rate, bps	**2.50E+06**
System Parameters	
Frequency, Hz	9.875E+09
Wavelength, meters	0.0304
Symbol Rate, sps	2500000.00
Range, km	789.57
Modulation Description	QPSK
Modulation Order, {sqrt(M-ary states)}	2
FEC Code Rate, Rc	0.5
Interference Level, rel dB	-100.00
Elevation angle at max range, deg	12.22
Gateway Transmitter	
Gain, dBi	41.24
Depolarization Loss	0.00
Transmitter Power, dBm	32.00
Transmit Power, watts	1.58
Backoff, dB	0.00
Antenna Cable Loss, dB	1.25
Antenna Pointing Loss, dB	0.00
Scan Loss	0.00
EIRP, dBm	71.99
EIRP, dBW	41.99
ERP, dBW	39.84
Satellite Receiver	
Antenna Temperature, K	50
Gain, dBi	15.44
Depolarization Loss	3.50
Receiver Line Losses	0.75
Receiver Noise Bandwidth, Hz	2.500E+06
Noise Figure, dB	1.50
Pointing loss, dB	0.50
Scan loss, dB	0.00
Net Receiver gain at antenna, dB	11.44
Noise Computations	
Boltzmann's Constant (k), J/K	1.38E-23
Line Loss Ratio	0.84
Ant temp	290.00
line temp ref to ant	54.67
Receiver Temp ref to ant	142.19
Background Noise	0.00
sys temp	486.85
Thermal Noise Power in Receiver, dBm	-107.75
Receiver G/T	-14.93
Link	
EIRP, dBm	71.99
Space loss, dB	-170.28
Net Receiver gain at antenna port, dB	11.44
Power Received, dBm	-86.85
Interference Received, dBm	-186.85
Noise plus Interference Power, dBm	-107.75
Propagation Losses, dB	0.20
Carrier to Interference + Noise (CINR), dB	20.70
Implementaton Loss, dB	2.5
Eb/No, dB	18.20
Required Eb/No, dB	1.05
Margin, dB	**17.15**