Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Spire Global, Inc.	)	File No. SAT-AMD-2017_____
	)	
Application to Amend	)	Call Sign: S2946
SAT-LOA-20151123-00078	)	
SAT-AMD-20161114-00107	)	

Phase IB/IC and Phase II Space Station License Amendment Application

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I. Description of Amendment

Spire Global, Inc. ("Spire") hereby amends its application for authority to deploy and operate its LEMUR-2 constellation.[1] Spire seeks authority to deploy up to 872 LEMUR-2 satellites (in the aggregate)[2] into the orbits referred to in Part II, using the frequencies referred to in Part III(C) below. Spire further requests to amend its application to include the service

[1] *See* Application of Spire Global, Inc., File No. SAT-LOA-20151123-00078 (filed Nov. 23, 2015) ("Initial Application"); Amendment Application of Spire Global, Inc., File No. SAT-AMD-20161114-00107 (filed Nov. 14, 2016) ("Phase IB/IC Amendment Application"). Spire's Initial Application and Phase IB/IC Amendment Application status is granted in part and deferred in part. *See* Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part Mar. 18, 2016, as corrected Mar. 24, 2016); Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part June 16, 2016); Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part Oct. 14, 2016); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part Apr. 7, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part May 18, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part July 13, 2017). The instant amendment application supplements Spire's Initial Application and incorporates by reference the remaining information provided by Spire in its Initial Application and Phase IB/IC Amendment Application.

[2] The FCC previously granted Spire authority only to launch twenty-eight Phase I satellites of the 900 satellites requested. The FCC deferred action on the remaining 872 Phase II satellites requested. To facilitate spectrum coordination discussions, Spire filed its Phase IB/IC Amendment Application. Spire requested additional deployment authority for a total of 100 satellites to be deployed over the 15-year term of the requested satellite license. The FCC granted Spire authority to deploy all twenty-eight Phase IB and seventy-two Phase IC satellites; however, those 100 Phase IB/IC satellites do not count toward the 900 satellites Spire originally requested. Spire now requests deployment authority for the remaining 872 Phase II satellites. **The number of simultaneously operational satellites will not exceed 175.** These Phase II satellites will be deployed at orbital altitudes from 385 to 650 km and inclinations ranging from equatorial to polar sun-synchronous (98 degrees).

classifications set forth in Part V below. Spire further requests the waivers set forth in Part VII below.

Spire is not seeking any changes to its authorized Phase I satellites.

Spire is seeking only one minor change to its authorized Phase IB/IC satellites. As set forth in Part VI(C) below, Spire requests 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 land surface[3] properties aboard its authorized twenty-eight Phase IB and seventy-two Phase IC satellites. Additionally, as set forth in Part IV, Spire may request authority in the future to host payloads on Phase IC satellites. Exhibit C (updated Orbital Debris Assessment Report ("ODAR")) includes information on the updated mass (nominal and maximum configurations) and surface area values.[4]

In Phase II, Spire requests authority to use multiple primary downlinks and uplinks to increase the flexibility it has to coordinate spectrum use with existing users and to operate in accordance with both the International Telecommunication Union ("ITU") and domestic (in foreign locations where Spire has ground stations) tables of frequency allocations. While Spire seeks authority on its satellites to use multiple primary downlinks and uplinks, only one primary downlink and uplink would be used for any one transmission to/from a ground station. The specific downlink and uplink frequency used for any specific transmission would depend upon Spire's discussions with third parties (including National Telecommunications and Information Administration ("NTIA")) with respect to a given domestic or foreign ground station location,

[3] Potential applications could include soil moisture and vegetation sensing, snow depth monitoring, sea ice mapping, etc.

[4] The LEMUR-2 Phase IC satellite will have a nominal launch mass configuration of 4.5 kg; the mass capacity may be up to 6 kg maximum, which accommodates potential other Spire or hosted payload(s). Surface area and spacecraft specifications are otherwise identical.

the allocation in the region in which the given ground station is located, and interference concerns with specific satellite or ground based systems. Such flexibility will allow Spire to efficiently use spectrum in a manner that does not interfere with existing users.

The Phase II satellites will have slightly different mass and surface areas due to the inclusion of new radios, antennas, and power systems, which will support X-band frequencies. The Phase II satellites, similar to Phase IC satellites, may also contain hosted payloads as described in Part IV below. Exhibit C (updated ODAR) includes information on the updated mass (nominal and maximum configurations) and surface area values.[5]

Grant of this application serves the public interest as it will permit Spire to continue to operate its state-of-the-art satellite maritime monitoring service. The high revisit times of the satellite system will enable the provision of critical near real-time Automatic Identification System ("AIS") and Application Specific Messages ("ASM") data of interest to shipping companies, harbor operators, governments, vessel traffic service data providers, and financial services companies. In addition, grant of this application will foster the development of a low-cost competitive AIS and ASM satellite constellation. Therefore, grant of this application serves one of the Federal Communications Commission's ("Commission's" or "FCC's") primary objectives of "promoting fair and vigorous competition in the satellites communications market."[6]

Spire recently completed the National Oceanic and Atmospheric Administration's ("NOAA's") first Commercial Weather Data Pilot program contract, where Spire was the only

[5] The LEMUR-2 Phase II satellite will have a nominal launch mass configuration of 4.5 kg; the mass capacity may be up to 6 kg maximum, which accommodates potential other Spire or hosted payload(s). Surface area and spacecraft specifications are otherwise identical.

[6] *Amendment of Part 25 of the Commission's Rules to Establish Rules and Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Service*, Notice of Proposed Rulemaking, 11 FCC Rcd 19841 ¶ 10 (1996).

operator that provided "space-based, radio-occultation data for the purpose of demonstrating data quality and potential value to NOAA's weather forecasts and warnings."[7] The weather data quality was as good or better than the existing COSMIC-1 government weather satellites. Approval of the Phase II satellites will allow Spire to roll out a full-scale meteorological constellation, delivering key inputs into the world's weather models.

In addition, grant of this application will enable Spire to provide a state-of-the-art, low-cost satellite service providing aircraft monitoring to help aircraft carriers meet regulatory mandates, including those promulgated by the Federal Aviation Administration, and to help complete a critical part of the United States ("U.S.") Next Generation Air Transportation System. To Spire's knowledge, only one other operator is currently planning to provide such a service. Therefore, grant of this application also serves the objective of promoting fair and vigorous competition in the provision of this service.

Finally, Spire's new hosted payload service will provide added benefits to the quickly growing low-Earth orbit ("LEO") market. Educational, government, and other commercial entities will have easier and quicker access to space as Spire will be deploying new satellites frequently. These entities, some of which may be financially constrained, will be able to deploy their innovative space technologies for a fraction of the cost. By utilizing Spire's Phase II small satellite ("smallsat") platform, these entities will also minimize the amount of spacecraft

[7] Press Release, The White House, Harnessing the Small Satellite Revolution to Promote Innovation and Entrepreneurship in Space (Oct. 21, 2016), https://www.whitehouse.gov/the-press-office/2016/10/21/harnessing-small-satellite-revolution-promote-innovation-and ("[T]he National Oceanic and Atmospheric Administration (NOAA) awarded the first Commercial Weather Data Pilot program contracts to smallsat-constellation operators GeoOptics, Inc. and Spire Global, Inc. to provide space-based, radio-occultation data for the purpose of demonstrating data quality and potential value to NOAA's weather forecasts and warnings."); *see also id.* (noting also that the White House Office of Science and Technology Policy will "promote and support both government and private use of small satellites for remote sensing, communications, science, and the exploration of space").

deployed into LEO and the burden on NTIA and others in coordinating active radiofrequency links.

For all these reasons, grant of this amendment would serve the public interest.

II. Deployments Requested

A. Phase I

Spire has authority to deploy twenty-eight Phase I satellites and has deployed all twenty-eight of those Phase I satellites.[8] It is not seeking any change to the deployment parameters of its Phase I satellites.

B. Phase IB/IC

Spire has authority to deploy twenty-eight Phase IB satellites and seventy-two Phase IC satellites, of which 24 of 28 Phase IB and 0 of 72 Phase IC satellites have been deployed to date.[9] Spire is not seeking any change to the deployment parameters of its Phase IB/IC satellites.

C. Phase II

Spire requests authority to deploy up to 872 Phase II LEMUR-2 satellites (in the aggregate) over its remaining license term; however, the number of simultaneously operational satellites on orbit will not exceed 175.

Given the potential long lead time for the instant application and state of the LEO launch market for secondary payloads, Spire is filing its license amendment application early and is not capable of providing launch parameters for the Phase II satellites at this time. However, it notes that these satellites (similar to the Phase I and Phase IB/IC satellites) will only deploy at orbital

[8] *See* Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part Oct. 14, 2016).
[9] *See* Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part Apr. 7, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part May 18, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part July 13, 2017).

altitudes from 385 to 650 km and inclinations ranging from equatorial to polar sun-synchronous (98 degrees).

Potential orbits will include deployments from the International Space Station ("ISS") and orbits above and in the same inclination as the ISS from spacecraft first docking at the ISS if, and only if, approved by the ISS program ("Above Station Deployments"). For each Above Station Deployment, Spire will supplement the record with documentation evidencing the National Aeronautics and Space Administration's approval of each Above Station Deployment.[10]

In support of the instant application and above deployment plan, Spire is providing an updated Orbital Debris Risk Mitigation Plan (see Exhibit B) and an updated ODAR (see Exhibit C) for the Phase II satellites that will be deployed into the above orbital parameters.

III. Frequencies Requested

A. Phase I

Spire is not seeking any changes to its Phase I satellites' frequencies. Phase I satellites use the frequency bands identified in the grant of authority relating to the Phase I satellites.[11]

B. Phase IB/IC

Phase IB/IC satellites use the frequency bands identified in the grants of authority relating to the Phase IB/IC satellites.[12] However, Spire requests additional authority to measure

[10] *See, e.g.*, Letter from Jenny Barna, Launch Manager, Spire Global, Inc., to Marlene H. Dortch, Secretary, FCC, File No. SAT-LOA-20151123-00078 (filed Aug. 19, 2016); *see also, e.g.*, Letter from Jonathan Rosenblatt, General Counsel, Spire Global, Inc., to Marlene H. Dortch, Secretary, FCC, File No. SAT-LOA-20151123-00078 (filed Sept. 30, 2016).

[11] *See* Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part Mar. 18, 2016, as corrected Mar. 24, 2016); Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part June 16, 2016); Stamp Grant, Spire Global, Inc., File No. SAT-LOA-20151123-00078 (granted in part and deferred in part Oct. 14, 2016).

[12] *See* Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part Apr. 7, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part May 18, 2017); Stamp Grant, Spire Global, Inc., File No. SAT-AMD-20161114-00107 (granted in part and deferred in part July 13, 2017).

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 land surface properties as set forth in Part VI(C) below.

C. Phase II

Table 1 below shows the frequency bands that Spire is seeking authority to use in Phase II. Bands emphasized in bold italics show differences from Phase IB/IC.

Table 1 - Phase II Active Frequencies

Frequency	Use	Comments
8025-8400 MHz (space-to-Earth)	***Primary data downlink TT&C downlink***	***Deferred in Phase I license grant***
2200-2290 MHz (space-to-Earth)	Data downlink	No change from Phase IB/IC Amendment Application
2020-2025 MHz (space-to-Earth)	Data downlink	No change from Phase I/IB/IC applications
401-402 MHz (space-to-Earth)	***TT&C downlink***	***Deferred in Phase IB/IC license grant***
2025-2110 MHz (Earth-to-space)	***Primary data uplink TT&C uplink***	***Deferred in Phase I license grant***
449.75-450.25 MHz (Earth-to-space)	TT&C uplink	No change from Phase IB/IC Amendment Application
402-403 MHz (Earth-to-space)	TT&C uplink	No change from Phase I/IB/IC applications
399.9-400.05 MHz (Earth-to-space)	***TT&C uplink***	***Deferred in Phase IB/IC license grant***

As discussed in pre-coordination with the U.S. Federal agencies, Spire prefers to have its operations in the following frequency bands: (i) primary data and TT&C downlink in 8025-8400

MHz, (ii) UHF TT&C downlink in 401-402 MHz,[13] (iii) primary data and TT&C uplink in 2025-2110 MHz, and (iv) UHF TT&C uplink in 402-403 MHz.[14]

Like Phase IB/IC, the Phase II satellites will also receive receive-only frequencies on certain AIS, ASM, and Automatic Dependent Surveillance-Broadcast ("ADS-B") bands. Spire also requests 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 land surface properties. These receive-only frequencies are listed in Table 2 below.

Table 2 - Phase II Passive Frequencies

Frequency	Use	Comments
161.9625-161.9875 MHz	Satellite receive only	No change from Phase I/IB/IC
162.0125-162.0375 MHz	Satellite receive only	No change from Phase I/IB/IC
156.7625-156.7875 MHz	Satellite receive only	No change from Phase IB/IC
156.8125-156.8375 MHz	Satellite receive only	No change from Phase IB/IC
161.9375-161.9625 MHz	Satellite receive only	No change from Phase IB/IC
161.9875-162.0125 MHz	Satellite receive only	No change from Phase IB/IC
1087.7-1092.3 MHz	Satellite receive only	No change from Phase IC
1164-1300 MHz	***Satellite receive only***	***Addition for Phase IB/IC/II***
1559-1610 MHz	***Satellite receive only***	***Addition for Phase IB/IC/II***

IV. Hosted Payload Service

Spire has announced that it will begin offering a hosted payload service, accommodating payloads from educational, government, and commercial customers.[15] This service will allow

[13] Spire's request to use 401-402 MHz (space-to-Earth) was deferred in the Phase IB/IC license grants. Spire is seeking authority to use 401-402 MHz so that it can operate in conformance with the ITU and various domestic (in foreign locations where Spire has ground stations) tables of frequency allocations. Spire believes it can provide even more separation in 401-402 MHz from NOAA's Data Collection Platform ("DCP") Geostationary Satellite Orbit ("GSO") satellites than where it is currently authorized in 402-403 MHz.

[14] Spire's request to use 402-403 MHz (Earth-to-space) was granted in the Phase IB/IC license grants. Spire requests to maintain its TT&C uplink operations in 402-403 MHz in Phase II as many of its ground stations are already fitted to operate in this frequency band and Spire can meet the current and proposed ITU-R recommendations protecting the DCP GSO operations in the band.

[15] *See Bespoke Sensors*, Spire, https://spire.com/data/custom-platform/ (last viewed November 6, 2017).

Spire customers to deploy space-based sensors with unprecedented speed and for fractions of the cost of buying their own satellite bus, launch slots, and ground station network.

These hosted payloads will be in approximately 1/3 of the Phase IC or Phase II satellite bus. In many cases a Phase IC or Phase II satellite will have no hosted payloads; however, when one of these satellites has a hosted payload, its mass may change. The Phase IC or Phase II satellite will have a nominal launch mass configuration of 4.5 kg (without hosted payload), but the mass may be up to 6 kg maximum (with a hosted payload). Recognizing that additional mass will increase orbital lifetime, Spire has designed a third solar drag panel that will help lower orbital lifetime. Spire will deploy the third solar drag panel on any satellites that exceed 4.5 kg and will eventually roll out the third drag panel across all future satellites. Surface area of any hosted payload is within the envelope of the Phase II satellite. Exhibit C (updated ODAR) includes information on both nominal and maximum mass configurations, which envelopes a Spire satellite both with and without hosted payloads.

Spire understands that a hosted payload will need to be (i) separately licensed by the International Bureau under the Part 25 rules[16] or by the Office of Engineering and Technology under the Part 5 rules (if appropriate)[17] by Spire or its customer, (ii) licensed via amendment to this application by Spire, (iii) licensed through the NTIA by a government customer, or (iv) licensed by a foreign administration. In some cases, such as a test payload for an optical communication link, no license may be necessary.[18] In any event, when Spire has sufficient

[16] *See generally* 47 C.F.R. Part 25.
[17] *See generally* 47 C.F.R. Part 5.
[18] FCC has consistently held that these optical transmissions fall outside its jurisdiction over radio communications. *See, e.g., TRW, Inc.*, 16 FCC Rcd 14407 ¶ 20 (IB 2001) ("Optical beam communications are not considered a type of radio communication since they operate at frequencies above 300 GHz, and they are not within the jurisdiction of the Communications Act."); *Hughes Communications, Inc.*, 16 FCC Rcd 14310 ¶ 16 (IB 2001) (same); *Teledesic LLC*, 14 FCC Rcd 2261 ¶ 14 (IB 1999) ("Because optical ISLs do not involve wire or radio frequency transmissions, the Commission does not have jurisdiction over the use of optical ISLs.").

details relating to a hosted payload, Spire will work with the Commission to license such payload under the appropriate mechanism.

V. Service Classifications

The Phase II satellites will provide the same services as the Phase IB/IC satellites. Those services include meteorological monitoring, maritime monitoring, and aircraft monitoring services, all of which should continue to be treated as an Earth Exploration-Satellite Service ("EESS") and, in the case of meteorological monitoring, a meteorological-satellite service ("METS").[19] In addition, maritime monitoring via AIS/ASM and aircraft monitoring via ADS-B are recognized as parts of the mobile-satellite service ("MSS").[20] In the U.S., Spire's services qualify as a Non-Voice Non-Geostationary MSS ("NVNG MSS").[21] Finally, Spire operates its own spacecraft, including tracking; space telemetry; and space telecommand, and should be treated as engaged in a Space Operation Service ("Space Ops").[22]

VI. New Frequencies

A. Primary Data and TT&C Downlink Band (8025-8400 MHz (space-to-Earth))

The 8025-8400 MHz band is allocated for EESS (space-to-Earth) on a primary basis across all ITU regions and to non-Federal operators in the U.S.[23] Spire wishes to add this band for primary data and TT&C data downlink transmissions.

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[19] *See* Initial Application, Exhibit A at 7-9; *see also* Phase IB/IC Amendment Application, Exhibit A at 11-12.
[20] *See* 47 C.F.R. § 2.1 (defining the Aeronautical Mobile Satellite Service as a "mobile-satellite service in which mobile earth stations are located on board aircraft"); *see also id.* (defining the Maritime Mobile-Satellite Service as a "mobile-satellite service in which mobile earth stations are located on board ships"); *see, e.g.*, *Applications by Orbcomm License Corp.*, Order and Authorization, 23 FCC Rcd 4804 ¶ 11 (IB and OET 2008); *Iridium Constellation LLC Application for Modification of License to Authorize a Second-Generation NGSO MSS Constellation*, Order and Authorization, 31 FCC Rcd 8675 ¶ 27 (IB and OET 2016) ("*Iridium Order*").
[21] *See* 47 C.F.R. § 2.1 (defining NVNG MSS as a "mobile-satellite service reserved for use by non-geostationary satellites in the provision of non-voice communications which may include satellite links between land earth stations at fixed locations"); *see also* Phase IB/IC Amendment Application, Exhibit A at 16-23.
[22] *See* 47 C.F.R. § 2.1 (defining Space Ops as a "radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry, and space telecommand").
[23] *See* 47 C.F.R. § 2.106 n.US258.

The following sub-sections show that Spire's Phase II operations comply with the ITU and U.S. requirements associated with this band.

i. Power Flux Density at the surface of the Earth in the 8025-8400 MHz band

Section 25.208 of the FCC's rules does not contain Power Flux Density ("PFD") limits at the earth's surface produced by emissions from non-geostationary satellite orbit EESS space stations operating in the 8025-8400 MHz band.[24] However, Table 21-4 of the ITU Radio Regulations states that the PFD at the Earth's surface produced by emissions from an EESS space station in the 8025-8400 MHz band, including emissions from a reflecting satellite, for all conditions and for all methods of modulation, shall not exceed the following values:[25]

- -150 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -150 + 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
- -140 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

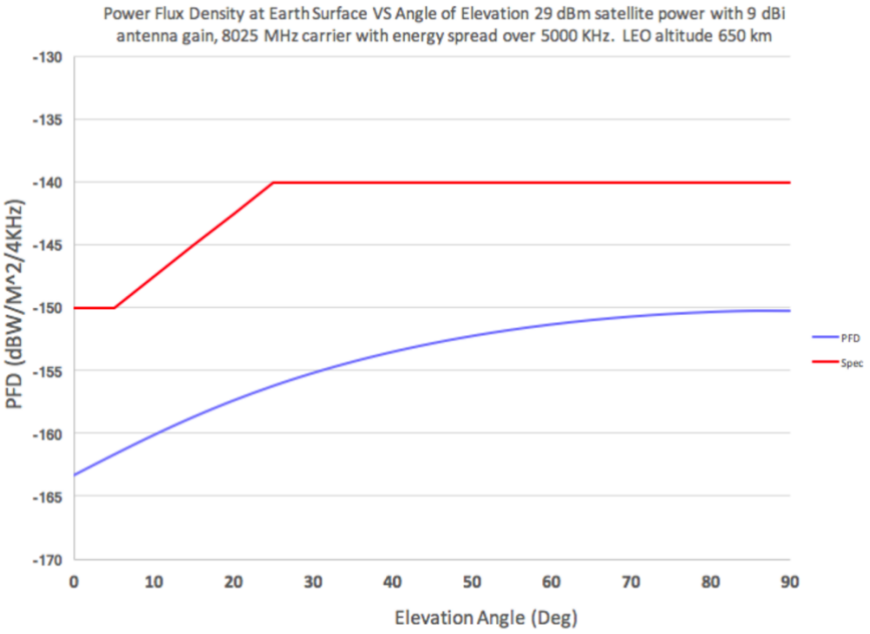
The PFD is calculated as follows:

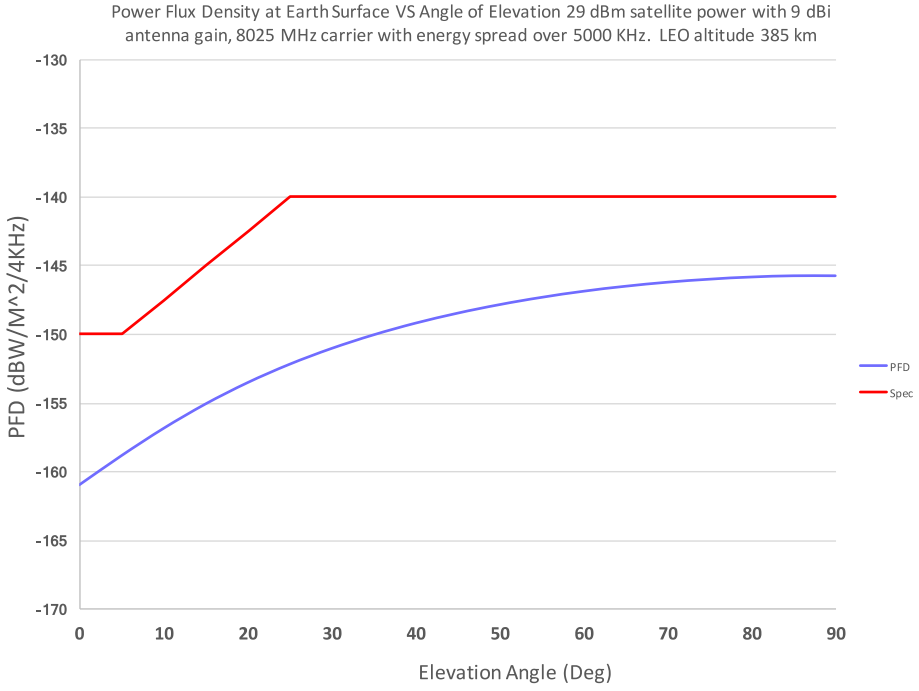
$$PFD\ [dBW/m^2/4\ kHz] = EIRP\ (dBW) - 11 - 20\log10(D) - 10\log10(BW) + 36$$

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.

Spire's satellites meet the ITU requirements as demonstrated in the following charts.

[24] *See* 47 C.F.R. § 25.208.
[25] *See* ITU Radio Regulations, Article 21, Table 21-4.


Power Flux Density at Earth Surface VS Angle of Elevation 29 dBm satellite power with 9 dBi antenna gain, 8025 MHz carrier with energy spread over 5000 KHz. LEO altitude 650 km
PFD (dBW/M^2/4KHz)
-130
-135
-140
-145
-150
-155
-160
-165
-170
0
10
20
30
40
50
60
70
80
90
Elevation Angle (Deg)
PFD
Spec


Power Flux Density at Earth Surface VS Angle of Elevation 29 dBm satellite power with 9 dBi antenna gain, 8025 MHz carrier with energy spread over 5000 KHz. LEO altitude 385 km
PFD (dBW/M^2/4KHz)
-130
-135
-140
-145
-150
-155
-160
-165
-170
0
10
20
30
40
50
60
70
80
90
Elevation Angle (Deg)
PFD
Spec

ii. PFD at the GSO in the 8025-8400 MHz band

ITU Radio Regulations No. 22.5 specifies that in the 8025-8400 MHz band, which is shared by EESS (space-to-Earth), Fixed-Satellite Service (Earth-to-space), and the MetSat (Earth-to-space), the maximum PFD produced at the GSO by any EESS space station shall not exceed -174 dbW/m^2/4 kHz.[26] The calculation below shows that the PFD produced by the transmission from a Phase II satellite would not exceed that limit even in the worst hypothetical case.

Using the worst case (*i.e.*, highest altitude) orbit of Spire's intended constellation (650 km), the distance to the geostationary orbit would be 35,136 km. At this orbital distance, for an antenna pointed towards the GSO having a maximum EIRP of 3 dBW in a 5 MHz bandwidth, the PFD at the GSO would be approximately –190 dBW/m^2/4 kHz.

iii. PFD at the surface of the Earth in the 8400-8450 MHz band

ITU-R Recommendation SA-1157 specifies a maximum allowable interference power spectral flux-density level at the earth's surface of -221 dB(W/Hz) to protect ground receivers in the deep-space research band operating in the 8400-8450 MHz frequencies.[27] Spire uses a combination of baseband digital filtering and hardware radio frequency filtering to achieve the ITU recommended protection for its out-of-band emissions in this frequency band. Additionally, Spire will not have (and is not seeking authority for) any transmissions above 8325 MHz, further protecting the adjacent deep-space research band.

[26] *See* ITU Radio Regulations, Article 22.5 § 4.
[27] *See* Recommendation ITU-R SA.1157-1 (Protection criteria for deep-space research) (2006).

iv. Interference between EESS systems operating in the 8025-8400 MHz band

Interference between the LEMUR satellites and those of other systems is unlikely because EESS systems operating in the 8025-8400 MHz band only transmit in short periods of time while visible from dedicated receiving earth stations. For interference to occur, satellites belonging to different systems would have to travel through the antenna beam of the receiving earth station and transmit at the same time. In this unlikely event, the interference could be avoided through coordination of the satellite transmissions and ensuring that they do not occur simultaneously. Spire will coordinate its satellite operations with other EESS operators in this band.

As the band is congested, Spire has already commenced coordination discussions with Federal and non-Federal operators in this band and hopes to quickly come to sharing agreements with these operators. Spire has also helped create the Commercial Smallsat Spectrum Management Association ("CSSMA").[28] Along with other initiatives, CSSMA's members look to pre-coordinate their applications in these bands. Summaries of Spire's use of these bands and technical characteristics have been sent to all CSSMA members who have a license grant in these bands with the Commission.

v. Adherence to ITU-R SA.1810 (system design guidelines for EESS operating in the band 8025-8400 MHz)

Recommendation ITU-R SA.1810 puts forth various guidelines that EESS operators should follow for when designing EESS systems that will operate in the 8025-8400 MHz band.

[28] *See generally Commercial Smallsat Spectrum Management Association*, www.cssma.space (last viewed Oct. 31, 2017). CSSMA is a trade association comprised of the world's leading smallsat companies. CSSMA seeks to create the conditions for a coordinated, transparent, and expedited spectrum coordination process among commercial smallsat spectrum users, government users, and other satellite and terrestrial users, and to advocate and represent the members' views on spectrum management and other policy matters that affect the smallsat community.

Spire confirms that its EESS system design for its 8025-8400 MHz operations will adhere to these guidelines.

B. Primary Data and TT&C Uplink Band (2025-2110 MHz (Earth-to-space))

The 2025-2110 MHz band is allocated for EESS (Earth-to-space) on a primary basis across all ITU regions and to non-Federal operators in the U.S. (subject to such conditions as may be applied on a case-by-case basis).[29] Further, transmissions from the satellites operating in this band shall not cause harmful interference to Federal and non-Federal stations operating in accordance with the U.S. Table of Frequency Allocations.[30] Spire will coordinate with Federal and non-Federal operators in this band to ensure compliance with this requirement.

C. Atmospheric and Land Surface Profiling Bands (1164-1300 MHz (space-to-Earth) and 1559-1610 MHz (space-to-Earth))

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 land surface[31] properties.

i. Signals that are readily accessible to the public

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"[32] or (ii) encrypted signal as long as it is not decrypted or decoded.[33] Although there are no explicit Commission

[29] *See* 47 C.F.R. § 2.106 n.US347; *see also Orbital Imaging Corporation*, Order and Authorization, 14 FCC Rcd 2997 ¶ 8 (1999).
[30] *See id.*
[31] Potential applications could include soil moisture and vegetation sensing, snow depth monitoring, sea ice mapping, etc.
[32] 18 U.S.C. § 2511(2)(g)(i).
[33] *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

rules preventing Spire from measuring readily accessible signals through the use of space station receivers,[34] the Commission may deny requested authorizations if they may cause potential foreign policy and national security concerns.[35]

The foreign policy and national security concerns that underlie the Commission's rules and policies 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 persons can detect, passively monitor, or measure the waveform modulations of signals in these frequency bands. Spire will only measure these waveform modulations' refraction, reflection, or other distortion for the purpose of inferring atmospheric and land surface properties, and it will not use these waveform modulations for the provision of any safety or position, navigation, or timing services.[36] 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.

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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.").

[34] *See generally* 47 C.F.R. Part 25.

[35] *See* 47 C.F.R. § 25.156(a) (stating that applications for a radio station authorization will be only be granted if the Commission finds that it will "serve the public interest, convenience and necessity").

[36] Spire will only rely on Global Positioning System signals for determining the position of its own satellites.

ii. Profiles derived through use of these signals are verified and quality controlled

All received waveform modulations in these frequency bands will be checked and verified against third-party sources, and any bad or false data will be readily identified.[37] For example, a weather model's assimilation system quality controls data inputs: "[i]nconsistencies between the observations and predictions are easily documented and demand explanation, providing the basis for quality control and validation of observations, analyses, and the models themselves."[38] Any waveform modulation spoofed to produce a faulty profile would be discarded through that quality control process.

Finally, Spire's profiles are additive data to existing weather models and thus will not be relied upon exclusively. If the additive data make the models work better, customers will buy the data; if they do not make the models better, customers will not buy the data. So, not only are the received waveform modulations subject to independent verification by Spire, the profiles are also subject to independent verification by Spire's customers.

iii. Signal measurements lead to advanced atmospheric and land surface data for a fraction of the current cost

NOAA will use these same frequency bands for atmospheric profiling operations with its six Constellation Observing System for Meteorology, Ionosphere, and Climate ("COSMIC")-2A satellites.[39] Due to funding constraints, NOAA and Taiwan's Ministry of Science and Technology agreed this year to scrap plans for a second set of six COSMIC-2B satellites, leaving

[37] *See Verify QC*, Veripos, https://www.veripos.com/software/verify-qc/ (last visited Nov. 22, 2017).
[38] NATIONAL RESOURCE COUNCIL, FOUR-DIMENSIONAL MODEL ASSIMILATION OF DATA: A STRATEGY FOR THE EARTH SYSTEM SCIENCES, at 48 (1991).
[39] *See, e.g.*, *FormoSat-7 / COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere and Climate)*, ESA https://directory.eoportal.org/web/eoportal/satellite-missions/f/formosat-7 (last viewed Nov. 7, 2017).

a potential gap in available critical weather data and showing the need for Spire satellites performing similar atmospheric profiling operations.[40]

To Spire's knowledge, only one other operator is currently using these frequency bands for land surface profiling operations.

With this authorization, Spire will be able to greatly increase the number of atmospheric and land surface profiles that Spire's constellation can derive, thus upgrading the capabilities of its system, promoting fair and vigorous competition in the provision of this service, and materially driving down the costs of critical weather and land surface data.

For the above reasons, grant of this authority would be in the public interest.

VII. Waiver Requests

The Commission may waive any of its rules if there is "good cause" to do so.[41] In general, waiver is appropriate if: (i) special circumstances warrant a deviation from the general rule and (ii) such deviation would better serve the public interest than would strict adherence to the general rule.[42] Generally, the Commission 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.[43] Spire submits that good cause exists to waive the rules below with respect to each frequency band in which Spire is seeking authority for its Phase II satellites to operate.

[40] *See* Jeff Foust, *U.S. and Taiwan cancel second set of COSMIC-2 satellites*, SpaceNews (Oct. 18, 2017), http://spacenews.com/u-s-and-taiwan-cancel-second-set-of-cosmic-2-satellites/.
[41] *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).
[42] *See Northeast Cellular*, 897 F.2d at 1166.
[43] *See WAIT Radio*, 418 F.2d at 1157.

A. Modified Processing Round Rules

Spire requests that this application be processed pursuant to the first-come, first-served procedure adopted for "GSO-like satellite systems" under Section 25.158 of the Commission's rules.[44] Spire incorporates by reference the waiver requests of Sections 25.156 and 25.157 of the Commission's rules[45] as provided in its Initial Application and Phase IB/IC Amendment Application.[46]

B. Default Service Rules

The Commission has not adopted band-specific rules for the services Spire proposes to provide. Spire incorporates by reference a waiver of the default service rules under Section 25.217(b) of the Commission's rules[47] as provided in its Initial Application.[48]

C. U.S. Table of Frequency Allocations

i. Downlink bands (2200-2290 MHz (space-to-Earth) data downlink, 2020-2025 MHz (space-to-Earth) data downlink, and 401-402 MHz (space-to-Earth) TT&C downlink)

Spire does not request a waiver of the U.S. Table of Frequency Allocations for its conforming use of the 401-402 MHz (space-to-Earth) with its Phase II satellites. This band is allocated for non-Federal space-to-Earth Space Ops on a primary basis.[49]

Spire requests a waiver of the U.S. Table of Frequency Allocations to use the 2200-2290 MHz (space-to-Earth) and 2020-2025 MHz (space-to-Earth) with its Phase II satellites on a non-conforming, non-harmful interference basis.[50] For its Phase II satellites, Spire incorporates by

[44] *See* 47 C.F.R. § 25.158.
[45] *See* 47 C.F.R. § 25.157.
[46] *See* Initial Application, Exhibit A at 21-22; Phase IB/IC Amendment Application, Exhibit A at 16-23.
[47] *See* 47 C.F.R. § 25.217(b).
[48] *See* Initial Application, Exhibit A at 22-23.
[49] *See* 47 C.F.R. § 2.106.
[50] *See* 47 C.F.R. §§ 2.102(a), 2.106. As a companion to Section 2.106, Spire also seeks waiver of 47 C.F.R. § 2.102(a). As the Commission recently stated, waiver of Section 2.102(a) is necessary to authorize the requested

reference the waiver requests as provided in its Initial Application and Phase IB/IC Amendment Application regarding its use of these frequency bands.[51]

Spire seeks to maintain its S-band downlink operations due to the latency requirements of its products and, secondarily, to enable flexibility in coordination due to the crowded nature of the X-band, possible limitation of operations above certain latitudes, and because X-band ground stations will take time to deploy.

Further, Spire also seeks to maintain its UHF-band downlink operations because these wide beamwidth links remain necessary to check out and stabilize smallsats. Spire has already commenced coordination discussions with Federal and non-Federal operators in these bands and hopes to quickly come to sharing agreements with these operators.

ii. Uplink bands (449.75-450.25 MHz (Earth-to-space) TT&C uplink, 402-403 MHz (Earth-to-space) TT&C uplink, and 399.9-400.05 MHz (Earth-to-space) TT&C uplink)

Spire does not request a waiver of the U.S. Table of Frequency Allocations for its conforming use of the 449.75-450.25 MHz (Earth-to-space) with its Phase II satellites. This band is allocated, through footnotes 5.286 and US87, for non-Federal Earth-to-space Space Ops.[52]

Spire does not request a waiver of the U.S. Table of Frequency Allocations for its conforming use of the 399.9-400.05 MHz (Earth-to-space) with its Phase II satellites. This band

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operations that are not in conformance with the Table of Frequency Allocations. *See Iridium Order* ¶ 21 n.77 (granting on its own motion waiver of Section 2.102(a) to permit Iridium Constellation LLC's ("Iridium's") proposed MSS (Earth-to-space) use of very high frequency ("VHF") bands in which there is no MSS allocation for the relevant use (domestic or international)). For convenience, all subsequent references to requests for waiver of the U.S. Table of Frequency Allocations refer to both Sections 2.102(a) and 2.106 of the Commission's rules.

[51] *See* Initial Application, Exhibit A at 24; Phase IB/IC Amendment Application, Exhibit A at 13-14.

[52] *See* 47 C.F.R. § 2.106 nn.5826, US87.

is allocated, through footnotes US319 and US320, for non-Federal space-to-Earth NVNG MSS operations.[53]

Spire requests a waiver of the U.S. Table of Frequency Allocations to use the 402-403 MHz (Earth-to-space) with its Phase II satellites on a non-conforming, non-harmful interference basis.[54] For its Phase II satellites, Spire incorporates by reference the waiver request as provided in its Phase IB/IC Amendment Application regarding its use of this frequency band.[55]

Spire has listed these multiple uplinks to increase the flexibility it has to coordinate spectrum use with existing users and to operate in accordance with both the ITU and domestic (in foreign locations where Spire has ground stations) tables of frequency allocations. Spire has already commenced coordination discussions with Federal and non-Federal operators in these bands and hopes to quickly come to sharing agreements with these operators.

iii. Maritime and aircraft monitoring bands (AIS 1 (161.9625-161.9875 MHz), AIS 2 (162.0125-162.0375 MHz), AIS 3 (156.7625-156.7875 MHz), AIS 4 (156.8125-156.8375 MHz), ASM 1 (161.9375-161.9625 MHz), and ASM 2 (161.9875-162.0125 MHz), and ADS-B (1087.7-1092.3 MHz))

For its Phase II satellites, Spire incorporates by reference the waiver requests as provided in its Phase IB/IC Amendment Application regarding its use of these frequency bands.[56]

D. Schedule S

Contemporaneously herewith, Spire is filing a new Schedule S to cover its Phase II satellites. The following bullets contain the differences between the new Schedule S and previously submitted versions of Schedule S.

[53] *See* 47 C.F.R. § 2.106; *see also* Phase IB/IC Amendment Application, Exhibit A at 16-23.
[54] *See* 47 C.F.R. §§ 2.102(a), 2.106.
[55] *See* Phase IB/IC Amendment Application, Exhibit A at 16.
[56] *See id.* at 24-26.

- "Operating Frequencies" tab – Added the following frequency bands: 1164-1300 MHz (space-to-Earth) and 1559-1610 MHz (space-to-Earth) for atmospheric and land surface profiling operations, 2025-2110 MHz (Earth-to-space) for data and TT&C uplink operations, 8025-8400 MHz (space-to-Earth) for data and TT&C downlink operations.
- "Orbital Information for Non-Geostationary Satellites" tab – Updated the total number of satellites in the active constellation to 175.
- "Orbital Planes" tabs – Updated the orbital planes to represent Spire's desired constellation configuration.
- "Receiving Beams and Channels" tab – Added beams and channels for the following frequency bands: 1164-1300 MHz (space-to-Earth) and 1559-1610 MHz (space-to-Earth) for atmospheric and land surface profiling operations, 2025-2110 MHz (Earth-to-space) for data and TT&C uplink operations.
- "Transmitting Beams and Channels" tab – Added a beam and channel for the following frequency bands: 8025-8400 MHz (space-to-Earth) for data and TT&C downlink operations.
- "NGSO Antenna Gain Contour Plot" attachments – The antenna contour plots have been updated to reflect the representative orbital parameters submitted in the "Orbital Information for Non-Geostationary Satellites" and "Orbital Planes" tabs.

Due to the limitations of the Commission's Schedule S software, Spire clarifies some of its responses provided in the Schedule S and, to the extent necessary, seeks waiver of Section 25.114(c) of the Commission's rules, which requires certain information to be filed in the Schedule S. In many cases, the Schedule S and Form 312 are not formulated to readily

accommodate non-traditional satellite systems, such as Spire's innovative smallsat system, and the information requested may be inapplicable, irrelevant, and/or burdensome to produce. The following bullets clarify some of Spire's Schedule S inputs.

- The orbital planes are representative of Spire's desired constellation configuration. As mentioned, given the potential long lead time for the instant application and state of the LEO launch market for secondary payloads, Spire is filing its Phase II license application early and is not capable of providing launch parameters for the Phase II satellites at this time. However, it notes that these satellites (similar to the Phase I and IB/IC satellites) will only deploy at orbital altitudes from 385 to 650 km and inclinations ranging from equatorial to polar sun-synchronous (98 degrees).
- The "Right Ascension of Ascending Node" and "Argument of Perigee" in each of the orbital planes is listed as "0 degrees," which is what the Schedule S software required Spire to input.
- The "NGSO Antenna Gain Contour Plots" are attached as PDFs on a per beam basis and include all orbits sought (but not all satellites on all orbits because they would not change from satellite to satellite within an orbit). ISS deployments are shown at 400 km, and Above Station Deployments are shown at 450 km, which are the most likely deployment scenarios.
- There is a primary and backup radio in each UHF frequency band, so that increases the number of beams, which is why some beams are labeled "P" (primary) and some beams are labeled "B" (backup).

In sum, strict application of the rules here is unnecessary to serve the purposes of the rules, which is to ensure that the Commission has all the relevant information to evaluate the

application. Because Spire has provided all relevant information in this Narrative and Schedule S, waiver of the certain Schedule S requirements is appropriate.[57]

VIII. Ownership Information Change

In Exhibit D, Spire has updated its ownership information.

IX. Conclusion

For the foregoing reasons, Spire respectfully requests that its license applications be amended to include the above information and waiver requests.

Respectfully submitted,

/s/ Jonathan Rosenblatt

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Dated: January 2, 2018

[57] *See* 47 C.F.R. § 1.3; *see, e.g.*, Stamp Grant, ViaSat, Inc., SAT-LOI-20140204-00013 (granted Jun. 18, 2014) (waiving Schedule S requirements because they were found to be unnecessary for the space station application).

Attachment 1 (Technical Certification)

We, Jeroen Cappaert and Joel Spark, hereby certify, under penalty of perjury, that we are the technically qualified persons responsible for the preparation of the engineering information contained in the technical portions of the foregoing application and the related attachments, that we are familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of our knowledge and belief.

/s/ Jeroen Cappaert
Jeroen Cappaert
Chief Technology Officer
Spire Global, Inc.

/s/ Joel Spark
Joel Spark
Chief Technology Officer
Spire Global, Inc.

Dated: January 2, 2018