Description of Application

Spire Global, Inc. ("Spire") requests authority to launch and operate a constellation of low-earth orbit, non-geostationary orbit ("NGSO") cubesats to provide maritime monitoring, meteorological monitoring, and earth imaging services.[1] As detailed in this narrative description ("Narrative"), the Spire satellite system, *i.e*. the LEMUR constellation, will be constructed in two phases. Phase I will employ 29 technically identical[2] cubesats operating at a number of different orbital altitudes and inclinations (the LEMUR-2 constellation). These satellites will use the 2020-2025 MHz band for downlink[3] and the 402-403 MHz band for uplink and telemetry, tracking, and command ("TT&C").[4] Phase II will employ up to 175 technically identical satellites, operating at orbital altitudes from 400 to 650 km and inclinations ranging from equatorial to polar sun-synchronous (98 degrees) (the LEMUR-3 constellation).[5] These cubesats will use the 8025-8400 MHz band for downlink, including TT&C, and the 2025-2110 MHz band

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[1] Cubesats are also referred to as nanosatellites, small satellites, small sats, or picosats, depending on context.

[2] The satellites have the same relevant radiofrequency characteristics (*e.g*., transmit power, out-of-band emissions, antenna patterns and gain, and transmit and receive frequencies).

[3] The Phase I satellites will also use the 402-403 MHz band for backup downlink. *See* Frequency Bands, Exhibit B (identifying the proposed frequency bands to be used on the LEMUR constellations); *see also infra* Part II.A.4 (discussing the frequency bands used by the LEMUR constellations).

[4] As discussed below, Spire already has received experimental authority for the launch and operation for several of the 29 Phase I satellites and is not seeking further authorization with respect to those previously authorized satellites or any subsequent Phase I satellite for which Spire receives experimental authorization.

[5] Spire expects the constellation, at any point in time, to be comprised of approximately 125 satellites.

for uplink, including TT&C.[6] Both the Phase I and Phase II satellites also will have equipment capable of receiving two Automatic Identification System ("AIS") signals, AIS 1 (161.9625-161.9875 MHz) and AIS 2 (162.0125-162.0375 MHz),[7] and also the Global Positioning System ("GPS") L1 signal (centered at 1575.42 MHz) and the L2 signal (centered at 1227.60 MHz).

Spire also requests launch authority for a total of up to 900 satellites to be deployed over the 15-year term of the requested satellite license. This authority will cover both the Phase I satellites (that have not been granted experimental authorizations as of the date of the grant of this application) and the Phase II satellites. Spire would have no more than 175 satellites operational at any given time and would only launch additional satellites, as necessary, to replenish its on-orbit fleet.

In support of its request for authorization, Spire provides the following information concerning its proposed satellite system.

I. <u>Description of the Applicant</u>

Spire, which was formerly known as NanoSatisfi, Inc. and formed in Delaware in August 2012, is a private U.S. company headquartered in San Francisco, California, with offices in Glasgow and Singapore. The enterprise grew out of a volunteer effort by four graduate students

[6] The Phase II satellites will also use the 2020-2025 MHz band for backup downlink band and the 402-403 MHz band for backup uplink and downlink, including for backup TT&C. *See* Frequency Bands, Exhibit B (identifying the proposed frequency bands to be used on the LEMUR constellations); *see also infra* Part II.A.4 (discussing the frequency bands used by the LEMUR constellations).

[7] *See, e.g., Amendment of Parts 1, 2, 15, 25, 27, 74, 78, 80, 87, 90, 97, and 101 of the Commission's Rules Regarding Implementation of the Final Acts of the World Radiocommunication Conference (Geneva, 2007) (WRC-07), Other Allocation Issues, and Related Rule Updates, et al.*, Report and Order, Order, and Notice of Proposed Rulemaking, 30 FCC Rcd 4183 ¶ 106 (2015) ("*WRC-07 Implementation Order*").

at the International Space University who began building a prototype nanosatellite as a platform for making space accessible and affordable to students. Early funding for the concept came from the crowdfunding website Kickstarter, where the original ArduSat (short for "Arduino-based satellite") concept raised more than $100,000 from nearly 700 private space enthusiasts.[8] Two ArduSats were released into orbit from the International Space Station on November 19, 2013 pursuant to an experimental authorization granted by the Office of Engineering and Technology ("OET").[9] Kickstarter funders and others used these satellites to test experiments, play games, take pictures, and run applications. For this pioneering work related to the ArduSats, the Obama Administration recognized Spire Co-founder and CEO Peter Platzer as a "Champion of Change."[10]

Building on the success and experience of the ArduSat satellites, Spire subsequently sought and received Federal Communications Commission ("FCC" or "Commission") authority to conduct a market trial with two, more advanced satellites, ArduSat-2 and LEMUR-1.[11] These satellites, which have more equipment and greater functionality than the prior ArduSats, were designed to explore the potential commercial viability of providing services for educational,

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[8] *ArduSat—Your Arduino Experiment in Space*, KICKSTARTER, https://www.kickstarter.com/projects/575960623/ardusat-your-arduino-experiment-in-space (last accessed May 27, 2015).

[9] *See* Application of Ardusat Inc., ELS File No. 0917-EX-ST-2012, Call Sign WG9XFC (granted Apr. 26, 2013); Application of Ardusat Inc., ELS File No. 0787-EX-PL-2013, Call Sign WG2XZS (granted Mar. 14, 2014).

[10] Peter Platzer, *Creating Next Generation Innovators Through Space Education*, WHITEHOUSE.GOV BLOG (Jun. 6, 2013), https://www.whitehouse.gov/blog/2013/06/06/creating-next-generation-innovators-through-space-education.

[11] *See* Application of NanoSatisfi, Inc., ELS File No. 0532-EX-PL-2013, Call Sign WG2XXW (granted Dec. 6, 2013); Application of Spire Global, Inc., ELS File No. 0213-EX-PL-2014, Call Sign WH2XCV (granted Apr. 25, 2014).

meteorological, aeronautical, and maritime markets. Both satellites also have earth-imaging capabilities and have been authorized by the National Oceanic and Atmospheric Administration ("NOAA").[12]

In 2015, Spire sought additional experimental authority for commercial validation of a more robust satellite system with more frequent revisit times.[13] The FCC has authorized the launch and operation of several of the satellites in that system, as well as the associated ground segment.[14] Four of those satellites have been successfully launched, and the other launches are scheduled for early 2016.[15]

As a result of the commercial validation of its system, Spire now seeks authority to begin deployment of a more robust cubesat system to provide maritime monitoring, meteorological monitoring, and earth imaging services.[16] Spire has a license with NOAA for its Phase I satellites and will submit another application to NOAA for the Phase II satellites prior to the launch of those satellites.

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[12] *See About the Licensing of Private Remote Sensing Space Systems*, NOAA, http://www.nesdis.noaa.gov/CRSRA/licenseHome.html (last accessed Sep. 22, 2015).

[13] *See* Application of Spire Global, Inc., Call Sign WH2XQT, ELS File No. 0041-EX-PL-2015 (granted Jun. 10, 2015). Spire initially sought experimental authorization for the limited satellite deployment, because of the frequencies proposed and the experimental nature of some of the equipment, including the S-band transmitter. OET partially granted the initial experimental application, noting that it would authorize only the initial launch, but invited Spire to modify the experimental authorization to include additional launches.

[14] *See* Application of Spire Global, Inc., ELS File No. 0041-EX-PL-2015, Call Sign WH2XQT (granted Jun. 10, 2015); Application of Spire Global, Inc., ELS File No. 0129-EX-ML-2015, Call Sign WH2XQT (granted Jul. 17, 2015).

[15] *See* Peter B. de Selding, *PSLV Rocket Launches India's 1st Astronomy Satellite, 4 Spire Cubesats*, SPACENEWS (Sep. 28, 2015), http://spacenews.com/pslv-rocket-launches-indias-1st-astronomy-satellite/.

[16] Spire has commenced construction of this system at its own risk. *See* Attachment 1 to this Narrative.

II. Information Required Under Section 25.114(d) of the Commission's Rules

A. General Description of Overall Facilities, Operations, and Services

1. Description of System

Both the Phase I and Phase II satellites are comprised of 3U cubesats.[17] Each Spire cubesat has a total mass of approximately five kilograms and an outer envelope of 10x10x34.5 centimeters (excluding the deployable antenna). Spire designs and conducts systems integration and testing for all its satellites.[18] The ground segment will be compromised of a network of geographically diverse earth stations, which will facilitate Spire's ability to communicate with its satellite network.[19] Each cubesat is designed to receive commands from a ground station and downlink the telemetry and data stored onboard the satellite as it passes over ground stations. There will be no inter-satellite communications. The satellites do not carry active propulsion, but can perform station-keeping and collision-avoidance maneuvers using differential drag and

[17] Cubesats follow a standard form factor that helps reduce the cost of launching small satellites into space by allowing for a common deployment system. *See, e.g.*, *CubeSat Design Specification*, California Polytechnic State University, http://www.cubesat.org/images/developers/cds_rev12.pdf (last visited Jul. 10, 2013). The basic unit for the cubesat form factor is a single 10-centimeter cube, weighing no more than 1.33 kilograms. The cubesat standard, however, is scalable along one axis, allowing up to three of these 10-centimeter cubes to be joined together (so-called "1U," "2U," and "3U" cubesats).

[18] Spire subcontracts to vendors, such as Clyde Space, the design and manufacture of some of the components of the satellites.

[19] In the United States, Spire intends to have approximately 15 transmit and receive earth stations located at or near some of the following locations: Anchorage, Alaska; Boca Raton, Florida; Ellicott, Colorado; Hartford, Connecticut; Juneau, Alaska; Naalehu, Hawaii; Piti, Guam; Richardson, Texas; Saint Croix, United States Virgin Islands; Salt Lake City, Utah; and San Francisco, California. Spire also intends to have additional earth stations in other countries. Spire will file separate applications, as necessary, for authority to operate all such earth stations.

an on-board attitude determination and control system.[20] The orbital period of the satellites will be approximately 90 to 97 minutes and will depend on the altitude of each orbital plane.

2. <u>Orbital Information</u>

The FCC has authorized the launch and operation several of the Phase I satellites under a separate experimental authorization, and Spire will continue to seek such experimental authorizations for additional launches of its Phase I satellites pending action on this application.

To be clear, Spire does not seek additional authority from the International Bureau ("Bureau") for those satellites that have been authorized pursuant to an experimental authorization. Spire will continue to operate the satellites granted under an experimental authorization consistent with the terms and conditions of those authorizations.[21] Spire requests that those Phase I satellites, for which Spire has sought (but not received) experimental authorization at the time of any grant of this application, be treated as part of this Part 25 application.[22]

The Phase II constellation will employ up to 175 technically identical satellites operating simultaneously and will have launch parameters within the following bounds:

- Minimum Circular Altitude: 400 km
- Maximum Circular Altitude: 650 km
- Maximum Apogee: 720 km (in the case of an elliptical orbit)

[20] *See infra* Part II.D.

[21] Because of the varying launch schedules of the Phase I satellites authorized under the experimental authorizations, it may be necessary to seek a modest extension of the terms of the experimental licenses, even after grant of this Part 25 application. This flexibility would allow for the full use of the authorized experimental satellites prior to their de-orbiting. Further, to ensure continuity of service, it may be necessary for Spire to seek experimental authority for additional satellites pending action on this instant application.

[22] Spire will withdraw any pending experimental application, as appropriate, upon grant of this application.

- Inclination: equatorial to polar sun-synchronous (98 degrees)

The specific orbital parameters will be determined based on launch availability and system coverage requirements at the time of replenishment. All of the replacement satellites will meet the National Aeronautics and Space Administration ("NASA") orbital debris guidelines.[23] Spire's launch approach is specifically designed to protect against risk of launch failures and launch schedule delays, which are beyond its control, as a secondary payload customer.

3. Services

Spire seeks to provide maritime monitoring, meteorological monitoring, and earth imaging services, which should be treated as both an earth exploration-satellite service ("EESS") and a meteorological-satellite service ("METS").[24] The Spire system will have global coverage and less than five-minute revisit times, providing near real-time maritime domain awareness and enhanced weather forecasting accuracy.

Maritime Monitoring. Maritime vessels with gross tonnage of 300 tons or more are required by international law to carry AIS transmitters.[25] Spire's satellites will passively monitor the AIS 1 signal and AIS 2 signal to track maritime activity.[26] Current maritime monitoring systems are generally land-based and do not offer the ability to track vessels when they are

[23] *See* NASA TECHNICAL STANDARD 8719.14, Process for Limiting Orbital Debris (Dec. 2011).

[24] *See* 47 C.F.R. § 2.1. EESS is defined as "[a] radiocommunication service between earth stations and one or more space stations, which may include links between space stations in which: (1) information relating to the characteristics of the Earth and its natural phenomena is obtained from active or passive sensors on earth satellites; (2) similar information is collected from air-borne or earth-based platforms; (3) such information may be distributed to earth stations within the system concerned; and (4) platform interrogation may be included." *Id.* METS is defined as "[a]n earth exploration-satellite service for meteorological purposes." *Id.*

[25] *See* The International Convention for the Safety of Life at Sea, Nov. 1, 1974, 32 U.S.T. 47, 1184 U.N.T.S. 3 (Dec. 2002 Amendments).

[26] To be clear, the Spire satellites will only receive in these frequencies.

outside of a 50-mile zone. Spire's satellite-based system will offer global coverage with revisit times of approximately five minutes, providing near real-time domain awareness, enabling more accurate maritime asset tracking, and enhancing security and protection against piracy and illegal fishing.

Meteorological Monitoring. Spire's satellites will passively monitor the GPS L1 signal and L2 signal.[27] Based on these GPS signals, the satellites will employ a technique called GPS-Radio Occultation to measure weather patterns.[28] The Spire system will enable the generation of sufficient data on a global basis to ensure accurate and timely weather predictions.

Weather monitoring technologies, such as GPS-Radio Occultation, are currently receiving attention because of a looming satellite data gap, resulting from the possible retirement of the Suomi-National Polar-orbiting Partnership weather satellite in October 2016 and the scheduled launch of its replacement, the Joint Polar Satellite System ("JPSS-1"), no earlier than March 17, 2017.[29] The Government Accountability Office estimates that this gap could be potentially as long as five years and eight months, as a result of possible delays in the launch or construction of JPSS-1.[30]

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[27] To be clear, the Spire satellites will only receive in these frequencies.

[28] GPS-Radio Occultation measures GPS transmissions that pass through the atmosphere. The magnitude of the refraction in the transmission will vary based on the temperature and water vapor concentration in the atmosphere. This measurement of the refractions will allow for enhanced weather forecasting models. *See, e.g.*, Anthony J. Mannucci *et al.*, *Generating Climate Benchmark Atmospheric Surroundings Using GPS Radio Occultations*, NASA (Jul. 2007), http://1.usa.gov/1bOUxEI.

[29] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-15-47, POLAR WEATHER SATELLITES NOAA NEEDS TO PREPARE FOR NEAR-TERM DATA GAPS 22 (2015), http://www.gao.gov/assets/670/667581.pdf.

[30] *See id.*

Indeed, the U.S. Government is considering legislation to assist commercial businesses in developing GPS-Radio Occultation technology in order to facilitate the provision of weather data to the government.[31] NOAA is also in the process of developing a new commercial space policy regarding the purchase of weather data.[32]

Earth Imaging. Spire's satellites will have two sensors onboard. The primary sensor is an electro-optical imaging system, which operates in the visible band with a ground resolution of approximately 12.5 m. The secondary sensor is a low-resolution infrared imaging system with an approximate ground resolution of 1 km. The images will be used primarily in connection with the maritime monitoring service as a supplementary data feature.

4. Frequencies

Spire requests authority to operate the Phase I satellites using the 2020-2025 MHz band for downlink and the 402-403 MHz band for uplink and TT&C.[33] The TT&C transmissions will include an automated beacon signal which will transmit a short, encrypted packet of satellite health data every ten seconds.[34] For redundancy purposes, the Phase I cubesats will also use the 402-403 MHz band for emergency backup downlink (*i.e.*, only in the event the primary communications link is lost, as a result of improper pointing, or other mishap, which is not expected to occur). The wide beamwidth of the low-band frequencies can greatly facilitate the reestablishment of a lost communications link. Because there is no satellite service allocation in

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[31] *See generally* H.R. 1561, 114th Cong. (2015).

[32] *See NOAA Commercial Space Policy*, Docket No. NOAA-NMFS-2015-0109 (Sep. 2015).

[33] *See* Frequency Bands, Exhibit B (identifying the frequency bands proposed to be used by the LEMUR-2 and LEMUR-3 constellations).

[34] The automated signal can be disabled, if necessary.

the 2020-2025 MHz band, the proposed use will be on a non-conforming, non-harmful interference basis.[35] Use of the 402-403 MHz band will also be on a non-conforming, non-harmful interference basis.

Spire requests authority to operate the Phase II satellites using the 8025-8400 MHz band for downlink and the 2025-2110 MHz band for uplink. TT&C will be provided in those frequency bands, as required by the Commission rules.[36] The 2025-2110 MHz and 8025-8400 MHz bands are allocated for EESS.[37] For redundancy and emergency backup purposes, Spire seeks authority to operate the Phase II satellites in the same frequency bands requested for the Phase I satellites.[38] The Phase II satellites will also transmit a satellite health beacon signal in the 402-403 MHz band, as explained above.

Both the Phase I and Phase II satellites also will have equipment capable of receiving in the AIS 1, the AIS 2, the GPS L1, and the GPS L2 bands. The AIS 1 and AIS 2 signals are allocated on a secondary basis for reception by mobile-satellite service satellites.[39] Similarly, the GPS L1 and GPS L2 frequencies are allocated on a primary basis, space-to-earth or space-to-space, for Radionavigation-satellites ("RNSS"), including for use in "spaceborne RNSS receivers

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[35] *See infra* Part III.B (requesting waivers of the FCC's rules).

[36] *See* 47 C.F.R. § 25.202(g).

[37] *See* 47 C.F.R. § 2.106; *see also* 47 C.F.R. § 2.1 (defining METS as "[a]n earth exploration-satellite service for meteorological purposes").

[38] *See supra* notes 33-35 and accompanying text; *see also* Frequency Bands, Exhibit B (identifying the frequency bands proposed to be used by the LEMUR-2 and LEMUR-3 constellations).

[39] *See* 47 C.F.R. § 2.106 notes 5.228 and US52; *WRC-07 Implementation Order*, 30 FCC Rcd 4183 ¶¶ 106-07.

for scientific and commercial applications."[40] Accordingly, Spire's proposed reception of the AIS 1, AIS 2, GPS L1, and GPS L2 signals is consistent with the U.S. Table of Frequency Allocations.[41]

B. Public Interest Considerations

As explained above, the grant of this application will permit Spire to launch and operate a state-of-the-art satellite service providing maritime monitoring, meteorological monitoring, and earth imaging services. The high revisit times of the satellite system will enhance maritime safety and enable high accuracy in weather forecasting. Data generated from the Spire system will provide critical near real-time data of interest to shipping companies, harbor operators, governments, vessel traffic service data providers, and financial services companies. For all of these reasons, grant of the application would serve the public interest.

C. Technical Description

The technical parameters are provided in the Schedule S of the Form 312. Due to the limitations of the commission's Schedule S software, Spire clarifies in this Narrative some of its responses provided in the Schedule S and, to the extent necessary, seeks waiver of any applicable requirement for the provision of certain information in the Schedule S.[42]

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[40] *See* 47 C.F.R. § 2.106; *Amendment of Parts 2, 25, and 87 of the Commission's Rules to Implement Decisions from World Radiocommunication Conferences Concerning Frequency Bands Between 28 MHz and 36 GHz and to Otherwise Update the Rules in this Frequency Range*, Report and Order, 18 FCC Rcd 23426, ¶¶ 3, 27, 33 (2003).

[41] *See* 47 C.F.R. § 2.106 notes 5.228, US52. To the extent necessary, Spire seeks waiver of the Commission's rules to permit reception of the AIS signals on its satellites. *See infra* Part III.C.

[42] *See infra* Part III.D.

1. Frequency Bands

a. 8025-8400 MHz Band

i. PFD at the Surface of the Earth in the 8025-8400 MHz Band

Section 25.208 of the Commission's rules does not contain Power Flux Density ("PFD") limits at the earth's surface produced by emissions from NGSO EESS space stations operating in the 8025-8400 MHz band. 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:[43]

- -150 dB(W/m) 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) 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) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

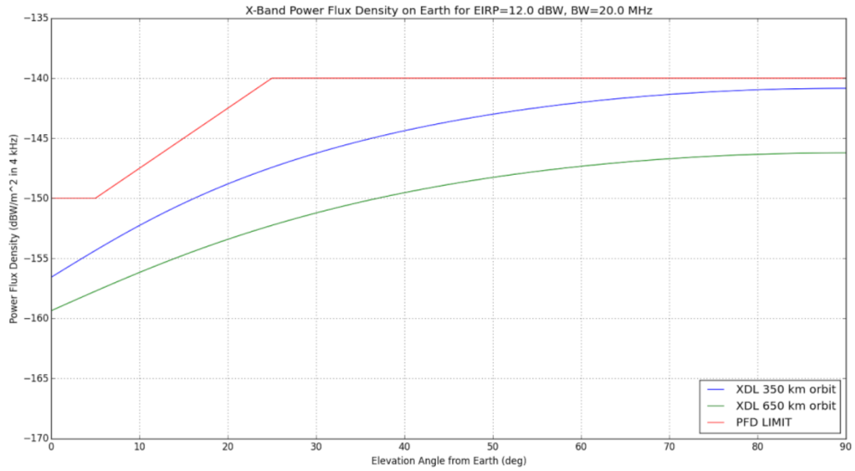
The PFD is calculated as follows:

PFD [dB(W/m / 4 kHz] = EIRP (dBW) – 71 – 20log10(D) – 10log10(BW) – 24

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.

[43] ITU Radio Regulations, Article 21, Table 21-4.

Spire's satellites meet the ITU requirements, as demonstrated in the chart below.[44]



ii. PFD at the Geostationary Satellite Orbit 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, fixed-satellite service (Earth-to-space), and the METS (Earth-to-space), the maximum PFD produced at the geostationary satellite orbit ("GSO") by any EESS space station shall not exceed -174 db(W/m) in any 4 kHz band.[45] The calculation below shows that the PFD produced by the transmission from a LEMUR 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 geostationary orbit having a maximum EIRP of 8 dBW in a 5 MHz

[44] Except for the automated, satellite health beacon, which can be disabled, transmissions from the satellites must be activated from the ground. Accordingly, the satellite is designed not to transmit during reentry.

[45] ITU Radio Regulations, Article 22, Section 4.

bandwidth, the PFD at the geostationary orbit would be approximately -184 dBW/m^2 in a 4kHz band.

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 -255.1 dB(W/(m Hz) to protect ground receivers in the deep space research band operating in the 8400-8450 MHz frequencies.[46] Spire uses a combination of baseband digital filtering and hardware RF filtering to achieve the ITU recommended protection for its out-of-band emissions in this frequency band.

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.

[46] ITU Recommendation SA.1157-1, *Protection criteria for deep-space research*, at 6 (2006).

b. 2025-2110 MHz Band

The 2025-2110 MHz band is allocated for non-Federal use for EESS (Earth-to-space) subject to such conditions as may be applied on a case-by-case basis.[47] 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.[48] Spire will coordinate with Federal and non-Federal operators in this band to ensure compliance with this requirement.

c. 2020-2025 MHz Band

There is a co-primary mobile-satellite service allocation in the 2020-2025 MHz band in ITU Region 2.[49] However, the band is not allocated for such services in the United States.[50] Neither the Commission rules nor the ITU Radio Regulations contain PFD limits at the earth's surface for emissions produced by space stations operating in the 2020-2025 MHz band.[51] However, in ITU Table 21-4, there are PFD limits for various bands allocated for space stations

[47] 47 C.F.R. § 2.106 note US347; *see also Orbital Imaging Corporation*, Order and Authorization, 14 FCC Rcd 2997 ¶ 8 (1999).

[48] *Id*.

[49] 47 C.F.R. § 2.106.

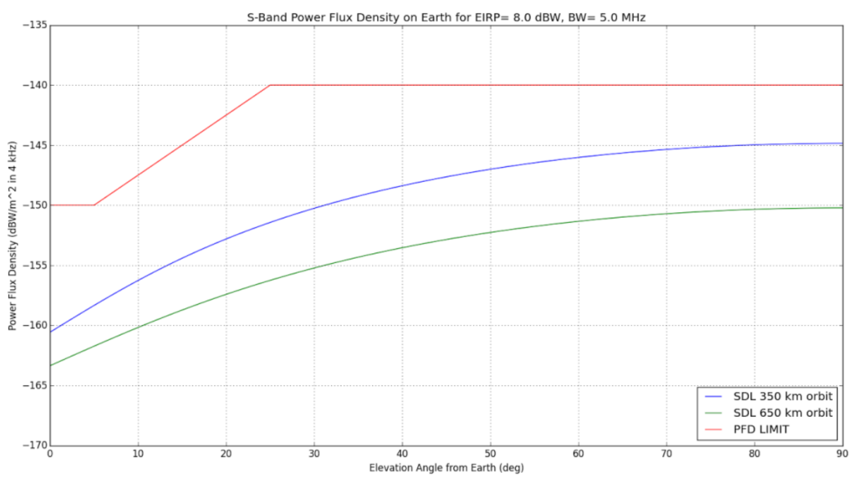
[50] *See infra* Part III.B (requesting waiver for use of this frequency band). The 2020-2025 MHz is allocated for fixed and mobile services but it is currently fallow and unlikely to be assigned until well after June 2016, when it will likely become more clear whether the 2000-2020 MHz band will be used for mobile uplink or downlink operations. *See also Amendment of the Commission's Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz Bands*, Report and Order, 29 FCC Rcd 4610 ¶ 59 (2014) ("*Commercial UHF Band Amendment R&O*").

[51] *See* 47 C.F.R. § 25.208.

between the 1525-2300 MHz range.[52] The PFD produced by emissions from a space station in this frequency range at the earth's surface shall not exceed the following values:

- -154 dB(W/m) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -154 + 0.5 (δ -5) dB(W/m) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -144 dB(W/m) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.[53]

Following is a chart illustrating the PFD at the surface of the Earth in the 2020-2025 MHz band:



Additionally, Spire will use a combination of baseband digital filtering and hardware RF filtering to ensure that its out-of-band emissions will not cause interference to licensed services in adjacent frequency bands.

52 ITU Radio Regulations, Article 21, Table 21-4.

53 *Id.*

d. 402-403 MHz Band

The 402-403 MHz band is allocated to a number of satellite services, including EESS and METS. Spire's proposed use of these frequencies is largely consistent with those allocations, and to the extent possible, Spire will coordinate with other operators in this band to ensure there is no harmful interference.[54]

D. Orbital Debris Mitigation

Spire confirms that its satellites will not undergo any planned release of debris. In addition, all separation and deployment mechanisms, and any other potential source of debris, will be retained by the spacecraft, launch vehicle, and/or deployment mechanism. Spire will also conduct acceptance level environmental testing of all satellites and a qualification test to provide further confidence in the structural integrity of the satellite in launch and space environments. Spire has assessed the probability of the satellites becoming sources of debris by collision with both large and small objects using NASA's Debris Assessment Software ("DAS") and has found its satellites to be fully compliant. A detailed Orbital Debris Assessment Report ("ODAR") is included in Exhibit D.

The only source of stored energy on the satellites is the Lithium-Polymer battery system. The 16 battery cells are charged before payload integration and provide electrical energy during the mission. The cells are recharged by silicon solar cells mounted on the deployable solar arrays. A battery cell protection circuit manages the charging cycle, performs battery balancing, and protects against over and undercharge conditions. The batteries will not be passivated at End

[54] *See infra* Part III.C (seeking applicable waivers of the U.S. Table of Frequency Allocations for use of these frequency bands).

of Mission due to the low risk and low impact of explosive rupturing. The maximum total chemical energy stored in each battery is ~144kJ.

Prior to the launch of the Spire's first four Phase I satellites, Spire entered into a sharing agreement with the Joint Space Operations Center ("JSpOC") to better coordinate collision avoidance measures and receive conjunction threat reports. Spire obtains satellite location information from its reception of GPS signals onboard the satellites and communicates that information to JSpOC. Spire also receives from JSpOC updated two-line element sets or TLEs, which facilitates the identification and tracking of Spire's satellites. JSpOC has a direct line to Spire's satellite operations team that is accessible 24 hours per day, seven days per week, to ensure that Spire can take immediate action to coordinate collision avoidance measures.

Spire has identified China's Tiangong-1 space module and Bigelow Aerospace's inhabitable space stations as the other man-rated space objects that require a high level of coordination for collision mitigation. Spire will provide the responsible organizations with the information needed to assess risks and ensure safe flight profiles, including a point of contact that will be available 24 hours per day, seven days per week to coordinate collision avoidance measures.

In addition to coordination and deployment sequencing efforts, each of the satellites will have the capability to perform collision avoidance using differential drag. Due to the two double-deployable solar array "wings," each satellite will have the ability to change its ballistic coefficient through an attitude maneuver using the onboard magnetorquers and reaction wheels. At all operational altitudes, any of the satellites can perform a collision-avoidance maneuver given approximately 24 hours' notice from a conjunction threat report.

The Commission's rules calls upon applicants to specify the accuracy, if any, with which the orbital parameters of their NGSO space stations will be maintained.[55] Because the Spire satellites will not carry maneuvering fuel, Spire will not maintain satellite inclination angles, apogees, perigees, and right ascension of the ascending node to any specified degrees of accuracy. The disclosure of the above parameters, as well as the number of space stations, the inclination of the orbital planes, and the orbital period to be used, can assist other parties in identifying potential conjunction threats. This information also permits coordination between Spire and other operators located in similar orbits.

The Commission's rules also calls for indication of the anticipated evolution over time of the satellites' orbits.[56] Spire's satellites will be in orbits that gradually decay over time until the satellites reenter the atmosphere. For the Phase I and Phase II satellites, the longest expected nominal orbital life at their proposed orbits is approximately eight years.[57] The outer limit of the orbital life for any satellite is approximately 20 years, assuming a very unlikely worst-case scenario in which the satellite is non-functional and both the solar arrays and the antennas fail to deploy.[58] Spire satellites are equipped with a nylon filament that decays after exposure to radiation and ensures that the antenna and solar panel will deploy over time, thereby increasing

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[55] 47 C.F.R. § 25.114(d)(14)(iii).

[56] *Id*.

[57] *See* LEMUR-2 Orbital Debris Assessment Report, Exhibit D §§ 1, 6. As discussed above, several of the satellites have already been authorized, and the discussion above does not include those satellites.

[58] *See* LEMUR-2 Orbital Debris Assessment Report, Exhibit D § 6.

the effective area-to-mass ratio and decreasing the orbital lifetime of the satellite.[59] Thus, under all circumstances, Spire's proposed satellites meet NASA's 25-year limit on orbital life.[60]

With respect to the post-mission disposal plan, Spire's satellites will burn up during re-entry with no surviving material reaching the ground.[61] This analysis was conducted using the DAS program and verified with higher fidelity models by the NASA Orbital Debris Program Office.

III. <u>Waiver Requests</u>

The Commission may waive any of its rules if there is "good cause" to do so.[62] In general, 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 general rule.[63] 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.[64] Spire submits that good cause exists to waive the following rules.

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[59] *See generally* Test Summary: Tensile Properties Test with Accelerated UV Aging and UV Weathering & Tensile Tests on Nanofil & Vantage Lines, Exhibit E (providing analysis regarding the filament decay).

[60] *See* NASA TECHNICAL STANDARD 8719.14, Process for Limiting Orbital Debris § 4.6.1 (Dec. 2011); *see also Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567, 11592, 11601 ¶¶ 61, 83 (2004).

[61] 47 C.F.R. § 25.114(d)(14)(iv).

[62] *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).

[63] *Northeast Cellular*, 897 F.2d at 1166.

[64] *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.[65] Spire requests waiver of Sections 25.156 and 25.157 of the Commission's rules, which stipulate the processing of "NGSO-like satellite systems" under a modified processing round framework.[66]

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.[67] Spire's satellite system provides, *inter alia*, a meteorological service and an earth imaging service, both of which meet the definition of an EESS.[68] 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. Because the purpose of the modified processing 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.[69]

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[65] *See* 47 C.F.R. § 25.158.

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

[67] *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*").

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

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

Spectrum sharing will be possible because the Spire satellites and satellites in other systems transmit only in short periods of time while visible from the dedicated receiving earth station. For harmful 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 exact same time. In such an unlikely event, the resulting interference could be avoided by coordinating the satellite transmissions so that they do not occur simultaneously. Accordingly, waiving Sections 25.156 and 25.157 will not undermine the policy objectives of these rules, and the waiver request is justified here.

B. <u>Waiver Request of Default Service Rules</u>

Spire requests a waiver of the default service rules under Section 25.217(b) of the Commission's rules.[70] The Commission has not adopted band-specific rules for the services Spire proposes to provide.

Although the Commission has not adopted band-specific rules for EESS NGSO operations, the Commission has previously granted a waiver of the default service rules contained in Section 25.217(b) to similarly situated NGSO EESS applicants, based on the fact that EESS operators are required to comply with technical requirements in Part 2 of the Commission's rules and applicable ITU rules.[71] In these cases, the Commission concluded that, because the cited requirements had been sufficient to prevent harmful interference, there was no need to impose additional technical requirements on operations in that band and, therefore,

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[70] *See* 47 C.F.R. §§ 25.106; 25.217(b).

[71] *See Space Imaging Order*, 20 FCC Rcd at 11973-74 ¶¶ 26-31; *DigitalGlobe, Inc.*, Order and Authorization, 20 FCC Rcd 15696 ¶¶ 1, 15 (2005); *see also* 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).

granted the waiver requests. These same reasons warrant waiver of the default service rules here.

C. <u>Wavier Request of the U.S. Table of Frequency Allocations</u>

1. <u>402-403 MHz Band</u>

Spire requests waiver of the U.S. Table of Frequency Allocations to use the 402-403 MHz band on a non-conforming, non-harmful interference basis. The 402-403 MHz band is allocated to a number of satellite services, including EESS (Earth-to-space), METS (Earth-to-space), and Meteorological Aids Service (radiosonde).[72] Spire's use of the band for its Phase I satellites will be of limited duration,[73] and its use of this band for its Phase II satellites will be for emergency backup purposes (*i.e.*, in the event the primary communications link is lost, as a result of improper pointing, or other mishap, which is not expected to occur) and for the beacon transmission of satellite health data. The wide beamwidth of the low-band frequencies can greatly facilitate the reestablishment of a lost communications link. In any event, there is unlikely to be harmful interference because of the infrequent nature and type of transmissions from the satellite system, as discussed above.[74] Additionally, to the extent possible, Spire will coordinate with other operators in this band to ensure there is no harmful interference.

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[72] *See* 47 C.F.R. § 2.106; *see also id*. at notes US64(a), US70, US384. The mobile service, excluding aeronautical mobile, is allocated to the Medical Device Radiocommunication Service operations on a secondary basis. *Id*. at note US64(a). The Meteorological Aids Service can operate associated ground transmitters. *Id*. at note US70. Finally, non-Federal EESS (Earth-to-Space) and METS (Earth-to-space) are permitted to only transmit to Federal space stations. *Id*. at note US384.

[73] The operational lifetime of a typical Spire satellite is approximately two years.

[74] *See supra* Part III.A.

2. 2020-2025 MHz Band

Spire requests waiver of the U.S. Table of Frequency Allocations to use the 2020-2025 MHz band on a non-conforming, non-harmful interference basis. Although there is a co-primary mobile-satellite service allocation in in the 2020-2025 MHz band for ITU Region 2, the frequency band is allocated only for fixed and mobile service in the United States.[75] However, the spectrum is currently fallow and unlikely to be used until well after June 2016, the deadline for the adjacent band licensee to determine whether the 2000-2020 MHz band will be used for terrestrial uplinks or downlinks.[76] Accordingly, Spire's temporary use of this band for its Phase I satellites will not cause likely harmful interference to any authorized operator. For its Phase II satellites, use of this band will be limited to emergency backup purposes and, therefore, unlikely to cause harmful interference. Moreover, as demonstrated above in Part II.C.1.c, Spire will meet PFD limits at the Earth's surface, established for adjacent frequency bands, further minimizing the possibility of harmful interference.

3. AIS 1 and AIS 2 Bands

The AIS 1 and AIS 2 bands are authorized for reception by satellites in the mobile-satellite service.[77] To the extent necessary, Spire seeks waiver of the Commission's rules to permit reception of the AIS signals on its proposed EESS/METS system. Because Spire would

[75] The 2020-2025 MHz is allocated for fixed and mobile services but it is currently fallow and unlikely to be assigned until well after June 2016, when it will likely become more clear whether the 2000-2020 MHz band will be used for mobile uplink or downlink operations. *See Commercial UHF Band Amendment R&O*, 29 FCC Rcd at 4636 ¶ 59.

[76] *See Commercial UHF Band Amendment R&O*, 29 FCC Rcd at 4636 ¶ 59.

[77] *See* 47 C.F.R. 2.106; *see also WRC-07 Implementation Order*, 30 FCC Rcd 4183 ¶¶ 106-07.

only receive the signals and would operate on a non-harmful interference basis, grant of the waiver would not undermine the service allocations in the U.S. Table of Frequency Allocations.[78]

D. Waiver of Schedule S Requirements

Spire also requests a limited 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 cubesat system, and the information requested may be inapplicable, irrelevant, and/or burdensome to produce.[79] For example, the Schedule S requests orbital information for all satellites. Given the number of satellites in the constellation and Spire's status as a secondary payload customer, Spire cannot practicably provide this information.[80] Spire has provided representative data that will allow the Commission to conduct an accurate technical assessment of Spire's system. 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 the Narrative and Schedule S, waiver of the certain Schedule S requirements is appropriate.[81]

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[78] *See Applications by Orbcomm License Corp.*, Order and Authorization, 23 FCC Rcd 4804 (IB and OET 2008) (granting waiver of the then-applicable U.S. Table of Frequency Allocations to permit satellite reception of AIS signals).

[79] To proceed forward in Schedule S, Spire was required to input a value for the receiver system noise temperature in Table S7, which is not required. *See* FCC Form 312 Schedule S, Table S7.

[80] *See* FCC Form 312 Schedule S, Tables S4-S5.

[81] *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).

IV. Additional/Other Considerations

A. Implementation Milestones

Spire is aware of the FCC's bond requirement for NGSO systems.[82] Spire will either post the full amount within 30 days of grant of this application or a reduced amount based on its satellite construction progress at that time, as approved by the Bureau.

As discussed above, Spire has constructed a number of its Phase I satellites and launched four of them successfully into orbit in September 2015.[83] However, because such satellites were authorized pursuant to an experimental authorization granted by the OET, Spire does not request reduction of its bond requirement based on those construction and deployment efforts.

B. ITU Advance Publication Materials and Cost Recovery

Spire has prepared the ITU Advance Publication Information submission for its proposed system, including the ITU Appendix 4 notification using SpaceCap software and will provide this information to the Commission under separate cover.[84]

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[82] *See* 47 C.F.R. § 25.165(a)(1).

[83] *See* Peter B. de Selding, *PSLV Rocket Launches India's 1st Astronomy Satellite, 4 Spire Cubesats*, SPACENEWS (Sep. 28, 2015), http://spacenews.com/pslv-rocket-launches-indias-1st-astronomy-satellite/ (Sep. 28, 2015).

[84] *See* 47 C.F.R. § 25.111(d).

V. <u>**Conclusion**</u>

Spire respectfully requests the Commission to grant the application for launch and operation authority as detailed herein.

	Respectfully submitted, */s/ Jonathan Rosenblatt*
Trey Hanbury Tony Lin Hogan Lovells US LLP 555 Thirteenth Street, NW Washington, D.C. 20004 202.637.5534 *Counsel to Spire Global, Inc.*	Jonathan Rosenblatt General Counsel Spire Global, Inc. 33 Norfolk Street San Francisco, CA 94103

Dated: November 23, 2015

ATTACHMENT 1

Notification of Commencement of Space Station Construction

Spire Global, Inc. (“Spire”), pursuant to Section 25.113(f) of the Commission’s rules, hereby notifies the Commission that it has commenced construction, at its own risk, of the satellites it proposes to launch and operate in the application associated with this notification.

ATTACHMENT 2

Technical Certification

I, Joel Spark, 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/ Joel Spark
Joel Spark
Lead Engineer Satellite Bus
Spire Global, Inc.

Dated: November 23, 2015