Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
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SWARM TECHNOLOGIES INC.	)	
	)	
Amendment to Application to Modify the	)	File No.
Authorization for the Swarm	)	
NGSO Satellite System	)	

AMENDMENT TO APPLICATION FOR MODIFICATION

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AMENDMENT TO APPLICATION FOR MODIFICATION

Pursuant to Section 25.116 of the Commission's rules, Swarm Technologies Inc. ("Swarm") hereby amends its pending application to modify its license to launch and operate a non-voice, non-geostationary ("NVNG") satellite system in the mobile-satellite service ("MSS") in the Very High Frequency ("VHF") bands.[1] Swarm submits this application for consideration as part of the non-geostationary satellite orbit (NGSO) satellite processing round the International Bureau established on March 5, 2020.[2]

The further modifications sought in this amendment would permit Swarm to increase the size of its constellation from 150 to 300 satellites and to communicate in additional VHF frequencies. They also would permit uplink transmissions of up to 1700ms from individual mobile earth stations operating in the 148.0–149.9 MHz band without a minimum wait time requirement, so long as each terminal observes a 1% duty cycle and avoids frequencies actively being used by

[1] *See* Swarm Technologies, Inc., Application to Modify the Authorization for the Swarm NGSO Satellite System, IBFS File No. SAT-MOD-20200501-00040 (filed May 1, 2020) ("Swarm May 1, 2020 Modification Application"); *Application of Swarm Technologies, Inc.*, Memorandum Opinion, Order and Authorization, 34 FCC Rcd. 9469 (Int'l Bur. 2019) ("*Swarm Grant*"). *See also* Swarm Technologies, Inc., Application for Authority to Launch and Operate Non-Voice, Non-Geostationary Lower Earth Orbit Satellite System in the Mobile-Satellite Services, IBFS File No. SAT-LOA-20181221-00094 (filed Dec. 21, 2018).

[2] *See Myriota Pty. Ltd., Petition Accepted for Filing, Cut-off Established for Additional NVNG MSS Applications or Petitions for Operations in the 137-138 MHz and 148-150.05 MHz Bands*, IBFS File No. SAT-PDR-20191118-00135, DA 20-238 (rel. Mar. 5, 2020) ("*VHF Processing Round Public Notice*").

terrestrial systems. If granted by the Commission, these additional modifications would expand the capabilities of Swarm's innovative satellite constellation, drive competition, and empower Swarm to deliver new, more robust services without unduly affecting incumbent operations.

I. INTRODUCTION

Based in Mountain View, California, Swarm is a U.S. NVNG MSS licensee seeking to make data accessible to everyone, everywhere on earth at a fraction of the cost achievable using traditional communications satellites. As a market leader in developing innovative NVNG MSS systems, Swarm designed its licensed constellation at a time when the marketplace for low-cost satellite data solutions and small-satellite launch services was just beginning to emerge. To keep pace with rapid market developments—and anticipated updates to the Commission's orbital debris rules—Swarm recently conducted a comprehensive reassessment of its system and the parameters governing its existing authorization. That review naturally resulted in a number of changes that would better equip Swarm to respond to market demand, while leveraging all available launch opportunities and promoting a safe space environment.

Based on that review, Swarm recently filed an application for modification seeking greater orbital altitude flexibility and approval for several space station design changes, including the implementation of onboard propulsion.[3] Those changes will help Swarm accelerate service deployment and further improve the trackability, maneuverability, spreading, deconfliction, and rapid de-orbit capabilities of its system.

In this amendment, which Swarm submits for consideration as part of the Commission's VHF Processing Round,[4] Swarm seeks additional modifications to accommodate increasing

3 *See* Swarm May 1, 2020 Modification Application.

4 *See VHF Processing Round Public Notice.*

demand for low-cost Internet of Things ("IoT") and Machine to Machine ("M2M") MSS connectivity from commercial and government users. Specifically, Swarm requests authority to deploy a constellation of up to 300 satellites (and to launch additional satellites, as necessary, to maintain an on-orbit fleet of 300 satellites) that would operate throughout the VHF NVNG MSS bands. Swarm also requests a modest, limited waiver of footnote US323 to support more users and unleash new uses of the 148–149.9 MHz band while still protecting terrestrial government operations.

Table 1 summarizes the modifications proposed in this amendment for consideration as part of the VHF Processing Round. Table 2 summarizes modifications previously sought in Swarm's pending modification application, IBFS No. SAT-MOD-20200501-00040.

Modifications for Consideration as Part of the VHF Processing Round		
Parameter	**Current Authorization**	**Proposed Modification**
Uplink (Earth-to-space) Spectrum	148.2500 – 148.5850 MHz 148.6350 – 148.7500 MHz 149.9000 – 149.9500 MHz	148.0000 – 150.0500 MHz
Downlink (space-to-Earth) Spectrum	137.0250 – 137.1750 MHz 137.3275 – 137.3750 MHz 137.4725 – 137.5350 MHz 137.5850 – 137.6500 MHz 137.8125 – 138.0000 MHz	137.0000 – 138.0000 MHz
Total Constellation Size	150 NVNG LEO Satellites	300 NVNG LEO Satellites To support additional customers, meet capacity demand, and provide robust service across the U.S.
US323 Compliance	In 148.0–149.9 MHz, assuming active frequency avoidance, uplink transmissions from any individual mobile earth station must observe a 1% duty cycle during any 15-minute period; a 450ms maximum duration; and wait time of 15s. *Summary*: In 148.0–149.9 MHz: - active frequency avoidance - 1% duty cycle in 15-min period - 450ms TX - wait 15s between TX	In 148.0–149.9 MHz, assuming active frequency avoidance, uplink transmissions from any individual mobile earth station must observe a 1% duty cycle during any 15-minute period and a 1700ms maximum duration. *Summary*: In 148.0–149.9 MHz: - active frequency avoidance - 1% duty cycle in 15-min period - 450ms TX → 1700ms TX ~~- wait 15s between TX~~

Table 1. A summary of Swarm's proposed modifications to be considered as part of the VHF Processing Round.

Modifications Sought in IBFS File No. SAT-MOD-20200501-00040		
Parameter	**Current Authorization**	**Proposed Modification**
Altitude Range	Operate: 300 – 550 km Deploy: 400 – 550 km	300 – 585 km (deploy and operate) Greater operational range will enable launches with more launch providers to more rapidly deploy and maintain the Swarm network
Onboard Propulsion System	n/a; current design supports differential drag maneuvers based on magnetorquer system	Dual mode cold gas / electric propulsion system on 1/4U spacecraft for additional maneuverability, spreading, deconfliction, and rapid de-orbit
Maximum Satellite Mass	0.45 kg	0.60 kg The additional mass will accommodate the propulsion system
Ku-Band Retro Reflectors	Included	Removal of Ku-radar reflectors in favor of GPS antennas with no reduction in trackability Additional satellite surface area will support custom-built GPS antennas to enable precise, real-time tracking of Swarm satellites on orbit

Table 2. A Summary of modifications to Swarm's existing space station authorization sought in IBFS File No. SAT-MOD-20200501-00040.

Grant of this application will serve the public interest by enabling Swarm to provide more services to more customers more rapidly, and to make more efficient use of the VHF bands without unduly affecting operations by other spectrum users. It also would equip Swarm to drive competition across the marketplace for global IoT and M2M connectivity. To bring innovative new services to market as quickly as possible, Swarm will press forward with planned launches of satellites that conform to its existing authorization as it continues to develop a more robust network based on the changes discussed herein.

II. NARRATIVE INFORMATION REQUIRED BY PART 25

The sections below contain information required by 47 C.F.R. § 25.114(c) that is not captured by the electronic Form 312 Schedule S, as well as information required by other provisions of 47 C.F.R. § 25.114 and Sections 25.142, 25.164, and 25.207 of the Commission's rules.[5]

A. ITU Information: § 25.111

Swarm understands that the International Telecommunication Union ("ITU") will impose cost-recovery fees for the ITU filing associated with Swarm's expanded constellation and accepts the requirement to reimburse the Commission for such fees. Swarm will also prepare and submit an appropriate Coordination Request for its system as modified, including appropriate ITU Radiocommunication Bureau SpaceCap files required under Appendix 4 for coordination or notification of a satellite network.

Swarm's VHF satellite system, called USASAT-NGSO-7, was filed by the United States. It was most recently published in Part I-S with IFIC No. 2917 on December 18, 2019. Swarm is currently undergoing timely bilateral coordination with Administrations under Provision 9.6 who responded to Special Section CR/C with IFIC No. 2901 on July 22, 2019.

[5] The information required by Section 25.114(c) of the Commission's Rules is contained in the Form 312, Main Form and Schedule S and in this narrative.

B. Description of the Network: § 25.114

As modified, Swarm's proposed constellation would be comprised of three hundred (300) satellites[6] in low Earth orbit ("LEO"). Each satellite will have a total mass up to 0.6 kg, and dimensions of approximately 11x11x2.8 cm (¼U cubesat form factor[7]), excluding the deployable antennas. The Swarm satellites will be stabilized using passive stabilization for coarse pointing[8] and a magnetorquer assembly for higher-precision pointing. Once ejected from the launch vehicle, each satellite will be commissioned and its antennas will be released 45 minutes after deployment. The satellites will have active propulsion and will also be capable of performing station keeping and collision avoidance maneuvers using differential drag.

As explained in the previously filed application for modification, Swarm proposes a diversity of deployment altitudes ranging from 300–585 km. The altitude of Swarm satellites will decrease over time due to natural orbital altitude degradation until the satellites ultimately passively re-enter the atmosphere. None of the spacecraft components are expected to survive re-entry or reach the Earth's surface. The minimum operational altitude at which Swarm satellites will transmit will be 300 km. Because Swarm satellites will operate at altitudes ranging from 300 to 585 km, calculations of power flux density levels at the Earth's surface were performed for a representative range of spacecraft altitudes, including the worst-case scenario of transmission from an altitude of 300 km.

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6 The satellites have identical radiofrequency characteristics, including transmit and receive frequencies, antenna gain and patterns, and transmit power. The mass of each satellite is up to 0.6 kg.

7 The CubeSat standard was created in 1999 by California Polytechnic State University, San Luis Obispo and Stanford University's Space Systems Development Lab. The basic unit for the cubesat form factor ("1U") is a 10x10x10 cm cube weighing less than 1.33 kg. Swarm satellites fit within standard CubeSat 1U, 3U, or 6U deployers.

8 *See* U.S. Patent Application No. 15/993,391 (filing date May 30, 2018) (Spangelo, Sara and Longmier, Benjamin, inventors).

The orbital period of the satellites upon deployment will be approximately 90 to 96 minutes depending on the deployed altitude. The nominal lifetime of the Swarm satellites is 5 years (see Table 3, below). The maximum lifetime of any deployed Swarm satellite, including a satellite rendered inoperative, is 7.9 years. As a precaution, all satellite hardware is designed for a reliability and hardware/software lifetime of 20 years. Table 3 shows the proposed number of satellites in each orbit and the corresponding orbital lifetime range. Future launches will replenish the satellites to ensure continued operation for at least 15 years under the proposed commercial license.

# Satellites in Operational Constellation	Altitude [km]	Inclination [°]	Nominal Lifetime [yrs]	Number of satellites deployed in given orbit over 15-year term
24	585	10	5.0	72
12	585	45	5.0	36
264	585	97-98 (SSO)	5.0	792
			Total	**900**

Table 3. Overview of Swarm constellation, as modified, including proposed number of satellites in each representative orbit and the orbital lifetime.[9]

The ground segment of the system will continue to operate as described in Swarm's initial space station application and existing earth station licenses. It will consist of a network of ground stations and mobile user terminals located both within and outside of the United States.[10] Ground stations will perform telemetry, tracking, and command ("TT&C") operations and uplink and downlink data to and from satellites as they pass overhead. Mobile user terminals will permit subscribers to send and receive data via the Swarm satellite constellation. As explained in Section

9 Swarm generated results using the National Aeronautics and Space Administration's ("NASA") Debris Assessment Software ("DAS") version 3.0.

10 Swarm has and will continue to file separate applications for authority to operate all such ground stations and user terminals with the appropriate administrations. *See, e.g.,* Swarm Technologies, Inc., Application for Authority to Operate a Gateway Earth Station in Wailuku, Hawaii, IBFS File No. SES-LIC-20191022-01365 (granted Jan. 13, 2020).

V, however, Swarm does request a limited waiver of certain footnote US323 requirements to permit higher throughput earth-to-Space transmissions from mobile user terminals operating in the 148–149.9 MHz band.

1) *Orbital Information*

Swarm's anticipated launch plan for initial deployment of its 300-satellite constellation is described in the Form 312 Schedule S submission accompanying this amendment. However, as a secondary payload customer, Swarm is subject to launch schedule postponements and orbital parameter changes dictated by launch providers and over which Swarm has no control. Swarm therefore requests authorization to deploy and subsequently replenish its constellation on launches with parameters within the following bounds:

- Inclination: equatorial (0 degrees) to polar sun-synchronous (98 degrees)
- Apogee: 300-585 km
- Perigee: 300-585 km
- Orbital period: 90-96 min

Launches will be selected based on availability and with the goal of optimizing global system coverage (see Figure 1, below). This launch strategy will protect the constellation from launch delays and failures, ensuring that Swarm can provide reliable connectivity and geographic coverage to its subscribers. Future launches of technically identical satellites will replenish the constellation of 300 satellites and enable continued operations.

Swarm's constellation would maintain its very strong space safety profile under these specified orbital parameters.[11] As an initial matter, Swarm plans to use its maneuvering capabilities, including its magnetorquer system and propulsion system, for collision avoidance and

[11] *See also* Swarm May 1, 2020 Modification Application at Narrative Exhibit, pp. 7-10.

to ensure its satellites do not exceed 585 km in altitude. Moreover, all Swarm satellites would be launched to a lower altitude than satellites operated by ORBCOMM, Iridium, and Globalstar, and the orbits proposed by Myriota,[12] Hiber,[13] and Amazon's Kuiper program.[14] They thus could not pose debris or collision risk for those satellite operators. Swarm also poses little risk for Space Exploration Holdings ("SpaceX"), who intends to move a fraction of their authorized satellites from an orbital altitude range of 1,100 km to 1,330 km to a new orbital altitude range of 540 km to 570 km.[15] Swarm agrees with SpaceX that both operators will "conduct active maneuvers to avoid collisions with both debris and other spacecraft throughout the life" of their satellites.[16] Indeed, Swarm's new propulsion system will enable its satellites to avoid operators who employ propulsive systems—like SpaceX's system—as well as non-propulsive systems or debris.

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12 *See* Myriota Pty Ltd, Petition for Declaratory Ruling to Access the U.S. Market using NVNG MSS Spectrum, IBFS File No. SAT-PDR-20191118-00135 (filed Nov. 18, 2019).

13 *See* Hiber Inc., Petition for Declaratory Ruling to Access U.S. Market Using the Hiberband Low-Earth Orbit System, IBFS File No. SAT-PDR-20180910-00069 (filed Nov. 10, 2018).

14 *See* Kuiper Systems LLC, Application for Authority to Launch and Operate a Non-Geostationary Satellite Orbit System in Ka-Band Frequencies, IBFS File No. SAT-LOA-20190704-00057 (filed July 4, 2019).

15 *See* Space Exploration Holdings, LLC, Application for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20200417-00037 (filed Apr. 17, 2020).

16 *Id.* at Narrative Exhibit, p. 11.

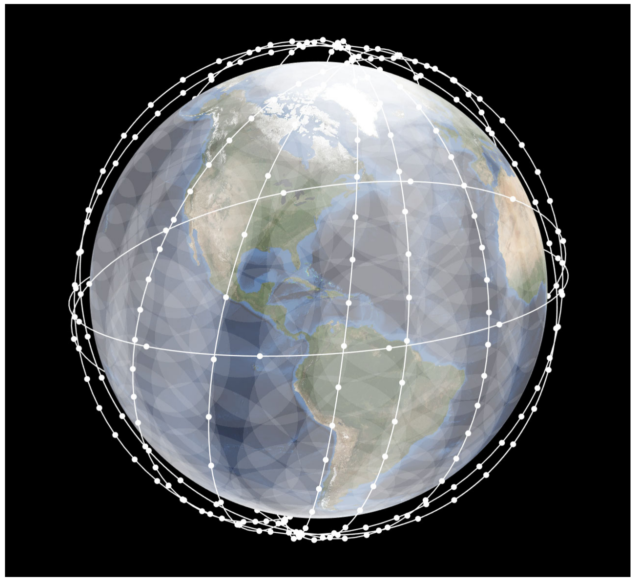

Figure 1. Swarm's proposed 300-satellite constellation will provide global two-way communications services.

2) Operations and Services

The basic description of Swarm's operations and services will not change as a result of the modifications proposed in this amendment. Swarm's proposed constellation, as modified, will continue to provide global two-way communication services, including service to the conterminous United States, Alaska, Hawaii, Puerto Rico, Guam, and all other U.S. territories.[17] User terminals will allow subscribers to transmit data to Swarm satellites, where the data is processed, downlinked to Swarm ground stations, and transferred via the Internet to a user-accessible web portal. Data can also be sent from a user web portal to a user terminal via the Swarm network. Swarm will provide connectivity services for private sector and government customers, as well as public service organizations and individuals. Swarm will offer its data services at a significantly lower cost than existing satellite services, providing connectivity to those that need it most, and in locations with poor or no connectivity in the United States and around the world.

[17] Pursuant to 47 C.F.R. § 25.142(b)(1), voice services will not be provided.

3) Satellite Design

The Swarm satellites use flight-proven software, hardware, and technology, including the following satellite subsystems:

- Flight Computer
    - Onboard processor
    - Memory
    - Temperature, voltage, current sensors
- Attitude Determination and Control
    - Passive attitude stabilization for coarse pointing
    - Active magnetorquer system for fine pointing and maneuvering
    - 9 DOF IMU
    - 3-axis magnetometer
    - GPS
- Power System
    - Lithium ion battery for energy storage
    - Solar cells
    - Power control and power distribution
- Dual Mode Propulsion System
    - Cold gas / Electric propulsion module
    - Green propellant reservoir, non-pressurized
- Communications System
    - Transmitter
    - Receiver
    - Antenna

A rendering of a Swarm satellite is shown in Figure 2. The antennas are released once in orbit.

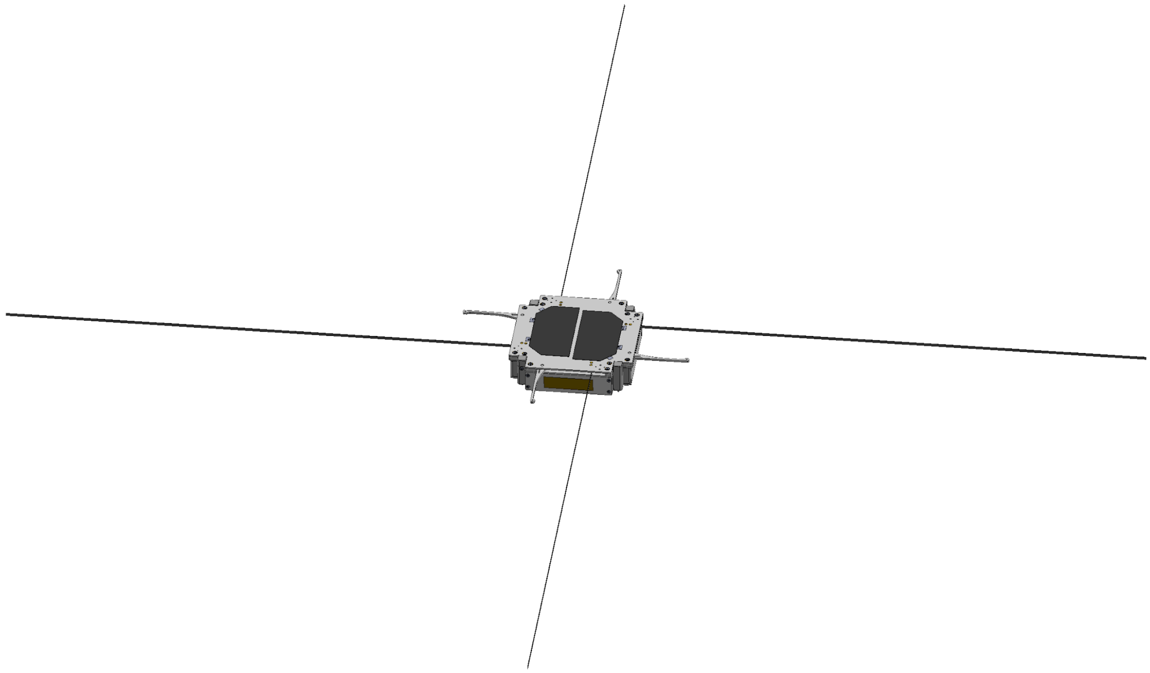

Figure 2. A CAD rendering of the Swarm satellite (antennas are cropped in this rendering). Antennas are 108 cm from tip to tip and are released once in orbit.

4) Communications Links and Frequencies

Swarm proposes to operate its system on the frequencies shown in Table 4, below, using the following communication links for two-way communications services for its customers, two-way data transfer between Swarm-operated ground stations and satellites, and for command and control of its satellites:

(i) Service Links:

The link between the satellites and user terminals will be conducted on frequencies within the 137–138 MHz band for space-to-Earth communications and the 148–150.05 MHz band for Earth-to-space communications. The length, interval, data rate, bandwidth, and frequency of broadcasts from satellites and user terminals are configurable by Swarm. The transmissions are sent using specific predefined channels using the F1D digital modulation type. The attached Form

312 Schedule S provides detailed frequency, bandwidth, and channel information for Swarm's nominal initial plan for communications links (*see also* Section II.B.5 and Tables 4 & 5 below).

(ii) Feeder Links:

Swarm does not propose to operate exclusive feeder uplink and downlink channels within its requested frequency assignment. Instead, customer data will be transferred between Swarm's ground stations and satellites on the uplink and downlink frequencies shown in Table 2, below.[18]

(iii) Telemetry, tracking, and command (TT&C):

Swarm does not propose to designate channels for the exclusive purpose of TT&C.[19] TT&C operations will be conducted on in-band links within the uplink and downlink frequencies shown in Table 4, below.[20] Command signals will be issued from Swarm's mission control centers and uplinked to the satellites from various ground stations that are operated by Swarm.

Lower Frequency (MHz)	Upper Frequency (MHz)	Transmit or Receive Mode	Nature of Service
137.0000	138.0000	Transmit (space-to-Earth)	NVNG MSS
148.0000	150.0500	Receive (Earth-to-space)	NVNG MSS

Table 4. Requested frequencies for the Swarm satellite system. Additional details are provided in Form 312 Schedule S.

5) Bandwidth of Communication Links

Swarm proposes to operate multiple channels within the requested uplink and downlink frequencies shown in Table 4. As described below, Swarm is capable of varying the bandwidth of

[18] The Form 312 Schedule S software allows only a single designation for each channel ("Feeder Link," "Service Link," or "TT&C"). Swarm requests that each of its uplink and downlink channels be authorized for communications service link operations for customers, feeder link operations between Swarm-operated ground stations and satellites, and TT&C operations.

[19] *Id.*

[20] Pursuant to 47 C.F.R. § 25.202(g), Swarm's TT&C signals cause no greater interference and require no greater protection from harmful interference than communications traffic on the Swarm network, and therefore may be transmitted in frequencies that are not at a band edge.

transmissions within its requested frequency bands. The data provided in this narrative and in the accompanying Form 312 Schedule S reflect Swarm's nominal initial plan for communications links, which consists of channels with a necessary bandwidth of 41.7 kHz and an assigned bandwidth of 50.0 kHz to account for Doppler shift and frequency tolerance. The proposed frequency assignments for each uplink and downlink channel are provided in the Form 312 Schedule S.

In order to allow Swarm to serve a range of current and future customer requirements, Swarm requests authorization to vary the bandwidth of channels to best address customer needs and maximize spectrum efficiency. Table 5 shows potential options for necessary bandwidth, assigned bandwidth, and power level for transmissions from a Swarm satellite.[21] In each case, the assigned bandwidth includes an appropriate frequency allowance to account for Doppler shift and frequency tolerance.

Table 5 also demonstrates that the proposed emissions will not exceed the -125.0 dBW/m^2/4kHz power flux density ("PFD") limit specified by the ITU above which coordination with terrestrial services is required,[22] nor will they exceed the -259.0 dBW/m^2/Hz limit in the 150.05–153.00 MHz band for protection of the radio astronomy service.[23] In addition,

[21] In the uplink direction, Swarm is also capable of varying the bandwidth of transmissions to address a variety of customer requirements and maximize spectrum efficiency. The potential bandwidths for uplink channels include those described in Table 3. In addition, Swarm is requesting sufficient spectrum to accommodate an uplink channel with a necessary bandwidth of 250 kHz and an assigned bandwidth of 258 kHz. Uplink transmissions from ground devices will comply with all applicable power and out-of-band emissions limits, and Swarm will file separate applications for authority to operate all such ground devices.

[22] *See* 47 C.F.R. § 2.106 at International Footnote 5.208; ITU R.R., Appendix 5, Annex 1 ¶ 1.1.1.

[23] *See* 47 C.F.R. § 2.106 at International Footnote 5.208A; ITU R.R. Res. 739 (Rev. WRC-15) and Recommendation ITU-R M.1583. As specified in ITU-R M.1583, the protection criteria is -238 dBW/m^2 in a 2.95 MHz reference bandwidth, and as recommended in ITU-R RA.769-2 Table 1, the threshold for harmful interference is -259 dBW/m^2/Hz at a center frequency of 151.525 MHz.

all emissions will comply with the out-of-band emission limitations specified in Section 25.202(f) of the Commission's rules.

Necessary Bandwidth (kHz)	Assigned Bandwidth (kHz)	Power Level (W)	Max PFD[24] ($dBW/m^2/4kHz$)	Maximum PFD[25] in RAS band (150.05-153.00 MHz) ($dBW/m^2/Hz$)
7.8	16.0	0.55	-126.0	-262.1
10.4	20.0	0.75	-125.9	-262.0
15.6	24.0	1.1	-126.0	-262.1
20.8	30.0	1.5	-125.9	-262.0
31.3	40.0	2.2	-126.0	-262.1
41.7	50.0	3.0	-125.9	-262.0
62.5	72.0	4.5	-125.9	-262.0
125.0	134.0	4.5	-129.0	-265.0
250.0	259.0	4.5	-132.0	-268.0

Table 5. Potential bandwidths, power levels, and PFD levels for Swarm satellite transmissions.

6) Predicted Antenna Gain Contours

The predicted space station antenna gain contours for the transmit and receive beams for a Swarm satellite are shown in Figure 3, below. The antenna gain contours are depicted on a projection of the Earth with the peak antenna gain for a space station pointed at nadir to a latitude and longitude within the proposed service area. The contours are plotted at -2, -4, -6, -8, -10, -15, and -20 dB relative to the peak antenna gain.

24 The maximum PFD corresponds to transmissions within the 137.0–138.0 MHz band at the minimum operational altitude of 300 km. PFD values were calculated using the necessary bandwidth to account for the worst-case (highest PFD) scenario.

25 *Id.*

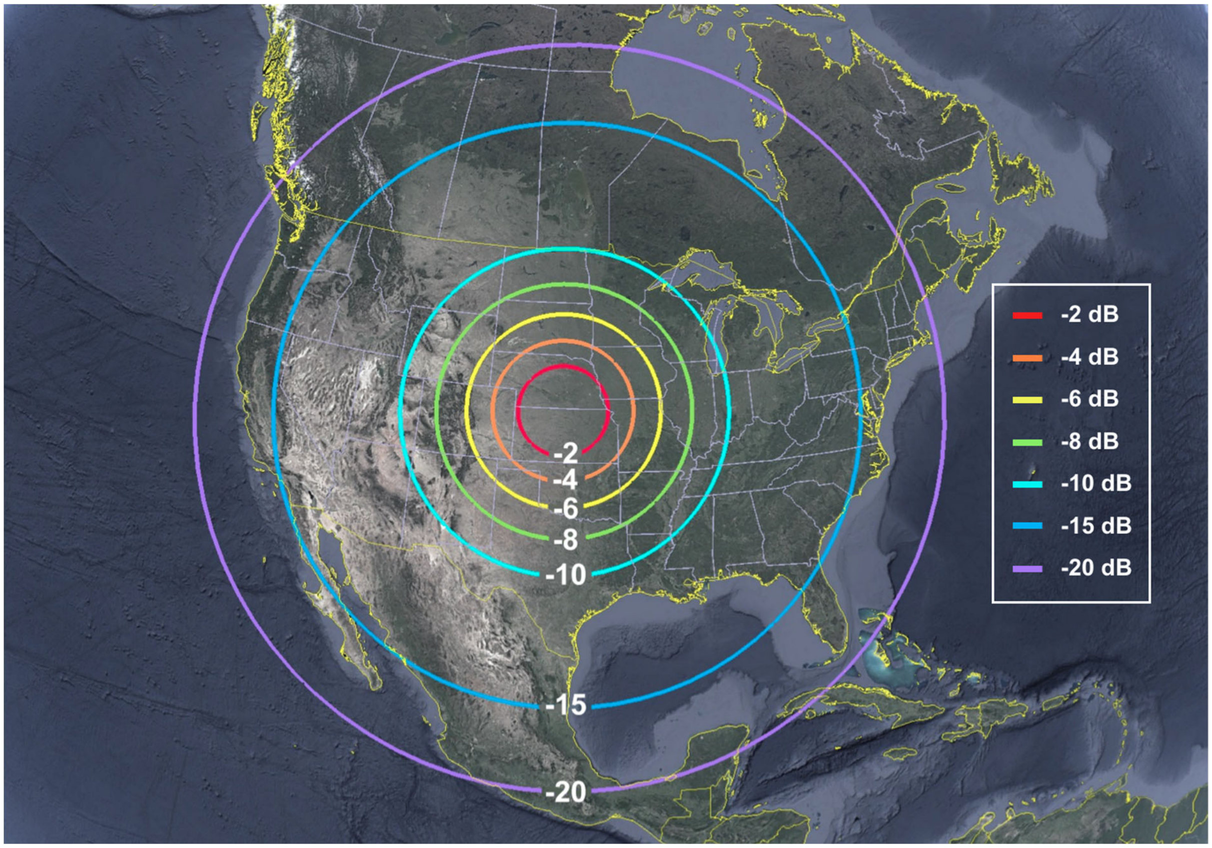

Figure 3. Antenna gain contours for a single Swarm satellite.

C. Orbital Debris Mitigation: § 25.114(d)(4)

1) Assessment and Limitation of Debris During Normal Operation

Swarm has prepared an Orbital Debris Assessment Report ("ODAR") of its modified constellation using NASA DAS version 3.0. The detailed ODAR is attached as Exhibit A. As discussed in the attached ODAR, the Swarm system, as modified, would remain compliant with all applicable NASA orbital debris requirements. A summary of that report follows.

Pursuant to Section 25.114(d)(14)(i) of the Commission's rules, Swarm will not undertake any planned release of debris, and no debris items will be released during deployment from the launch vehicle or release of the antennas. With the exception of the antenna deployment process and an internal propulsion system valve, there are no moving parts on the satellite, and no flotsam is ever generated. More than 500 tests of antenna deployments were performed in a thermal vacuum chamber to simulate the conditions in LEO.[26] The antenna deployment mechanism currently has a 100 percent success rate, and no debris was generated during any of the antenna deployment tests. Seven Swarm satellites currently on orbit used this antenna release mechanism successfully.

Post-mission disposal is accomplished via natural atmospheric drag forces and does not require that any of the satellite subsystems be operational. This ensures timely de-orbiting in all potential mission scenarios. Although Swarm plans to employ an on-board propulsion system to aid in post-mission disposal, functional operation of this system is not required for the satellites to meet disposal requirements.

Swarm recognizes the growing importance of active in-space propulsion systems for collision avoidance and has developed its green propellant propulsion system for this purpose.[27] Swarm is working with multiple range safety groups including the U.S. Air Force 30th Space Wing, as well as multiple private commercial groups to ensure that the system is compatible with launch safety procedures.

2) Assessment and Limitation of Accidental Explosions

Swarm has assessed and minimized the probability of accidental explosions before, during, and after the completion of the mission operations. The Swarm satellites do not have momentum wheels onboard.

Swarm satellites will include a dual mode cold gas / electric propulsion system. The non-toxic green propellant is stored in a non-pressurized reservoir but expelled as a cold gas or plasma. There is no credible method for the propellant tank to over-pressurize. Even in the case where the

[26] Tests were conducted at the same vacuum pressure level and thermal environment present in LEO.

[27] *See* Swarm May 1, 2020 Modification Application at Narrative Exhibit, pp. 4-5.

battery were allowed to heat the propellant without software feedback or temperature limit switches activating, it would only raise the temperature of the satellite and propellant by 85 C, from -20 C to 65 C in a thermal runaway scenario, which is well within the structural limits of the propellant reservoir with a 4x margin. A micrometeorite strike theoretically could puncture the propellant reservoir, potentially causing a slow release of propellant into space. But multiple barriers and tank wall thicknesses have been designed to mitigate against propellant release from micrometeorite strikes. And there is no possibility of persistent droplets nor persistent solids, as the propellant exists in the gaseous phase in the vacuum of space.

The only other source of stored energy on the Swarm satellites is a single rechargeable lithium ion battery. At the end of life of the satellite, the battery will be put into a permanently discharged mode. The lithium ion battery has been tested extensively in a thermal vacuum chamber with over 500 thermal cycles and 5,000 charge/discharge cycles at more extreme temperature ranges than are experienced in LEO. Lot and batch testing are also performed by the manufacturer for UN 38.3 certification, and acceptance testing was performed at Swarm's testing facilities on all batteries used for spaceflight.

3) Assessment and Limitation of Collisions

As required under Sections 25.114(d)(14)(i) and 25.114(d)(14)(iii) of the Commission's rules, Swarm has assessed the probability of the satellites becoming sources of debris by collision with both small and large objects, and an assessment using NASA's DAS tool has found Swarm's constellation to be fully compliant. In every scenario evaluated, including the worst case (longest lifetime) scenario of a satellite deployed in a 585 km orbit over a minimum solar activity period, the lifetime probability of collision for a Swarm satellite was less than 4e-7. In addition, the aggregate probability of collision for the constellation, including the initial deployment of 300 satellites and the subsequent deployment of satellites required to maintain the 300-satellite constellation over the 15-year license term, was assessed. The aggregate probability of collision for the constellation was found to be at most 0.00034, significantly lower than the maximum value of 0.001 set forth in NASA Requirement 4.5-1.[28]

To the extent possible, Swarm will select orbits that are dissimilar to the orbits of other satellites in LEO. Because Swarm proposes to deploy a number of its satellites into sun-synchronous orbits (SSOs) that may have an increased likelihood of congestion, Swarm is willing to coordinate with other satellite operators in these and any other populated orbits. Swarm does not rely on coordination with other satellite operators for avoidance maneuvers but will do so to the extent possible. Swarm will provide other satellite operators with a point of contact that will be available twenty-four hours per day, seven days per week to relay the information needed to assess risks and coordinate collision avoidance measures. The Swarm satellites can perform collision avoidance maneuvers using either on-board propulsion or an onboard magnetorquer system that allows the satellite to maneuver into a high- or low-drag state (see Figure 4, below).

Swarm is in contact with the Combined Space Operations Center ("CSpOC") to receive conjunction threat reports for its 4 experimental 1/4U satellites and 5 experimental 1U satellites currently on-orbit, and Swarm will continue to remain in contact with CSpOC to coordinate conjunction events with all current and future satellites.[29] Swarm will also actively track its satellites with onboard GPS, with such GPS data transmitted to the Swarm ground stations at regular intervals. Swarm has an ongoing contract with LeoLabs, a private company offering space

28 *See* Exhibit A: ODAR.

29 As a supplemental step, Swarm has contracted with LeoLabs, a private company specializing in the tracking of satellites and orbital debris, to provide a second source of tracking and potential collision data that can supplement the data provided by the Space Surveillance Network.

situational awareness data and reports, and will continue to contract with LeoLabs for additional and supplemental space tracking data, situational awareness, and conjunction warnings. Swarm will provide both active and passive tracking data to other satellite operators upon request.

Swarm will take precautions to reduce the probability of collision with the International Space Station ("ISS") and reduce the need for avoidance maneuvers. As an initial matter, and as mentioned above, the summed, aggregate probability of collision between the entire Swarm satellite constellation and any trackable object over the duration of the 15-year license term is 0.00034, which is significantly less than the 0.001 value established in NASA Requirement 4.5-1. To further reduce the probability that the ISS will have to perform a Debris Avoidance Maneuver ("DAM") due to a Swarm satellite, Swarm satellites will use their onboard propulsion to rapidly transit the ISS altitude (which, from 2016 to 2020, has hovered between 400 and 425 km). This operation will minimize the time that Swam satellites spend near the ISS altitude, and goes above and beyond the typical protocol for satellite avoidance of the ISS. Swarm will also work closely with CSpOC and the ISS program to respond to conjunction warnings and, if necessary, coordinate avoidance maneuvers. The orbital data provided by LeoLabs will also provide advance warning of potential conjunctions between Swarm satellites and the ISS.

A detailed analysis of the trackability of Swarm's 1/4U satellites is attached as a separate exhibit,[30] which demonstrates that the Swarm 1/4U satellites can be persistently detected and persistently tracked with comparable precision to a standard 1U satellite by normal means through the Space Surveillance Network (SSN). The satellites can also be tracked by normal means through

30 *See* Exhibit B: Trackability Analysis.

the LeoLabs radar network.[31] Swarm's 1/4U satellites have a radar cross-sectional area that is equal to, or larger than, 1/2U Aerospace Corporation satellites (NORAD IDs 40045 and 40046) and 1U STEP CUBE LAB (NORAD ID 43138) and 1U FOX-1D (NORAD ID 43137) satellites. In addition, the Swarm satellites have detection rates and orbit accuracies that are equal to, or greater than, the aforementioned 1/2U and 1U satellites.[32]

The orbits of the Swarm satellites will naturally decay over time due to atmospheric drag. The onboard propulsion system will provide the ability to modify orbital parameters quickly enough to avoid a potential collision in a close conjunction scenario. The propulsion system will also provide Swarm with the ability to de-orbit its satellites upon command from the ground, and to phase the satellites within their orbital plane more quickly than by drag differential alone. Swarm has chosen to deploy its constellation with a maximum apogee and perigee altitude of 585 km. According to analysis with NASA's DAS program, the typical orbital lifetime of a Swarm satellite with an apogee and perigee altitude of 585 km altitude is 5 years (see Table 3, above), and the maximum lifetime of a Swarm satellite with an apogee and perigee altitude of 585 km altitude is 7.9 years (due to the worst case solar cycle conditions within the 15 year grant period), which is less than the NASA standard for maximum orbital lifetime of 25 years[33] and less than the FCC commercial grant timeline of 15 years.[34] In the nominal case, most satellites will deorbit in less than 5 years. Swarm takes advantage of the natural atmospheric drag at the proposed altitudes to ensure that no satellite malfunction will render a satellite unable to de-orbit in a timely fashion. If

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31 LeoLabs conducted radar measurements and analyzed the trackability and detectability of Swarm's 1/4U satellites currently on orbit. A report from LeoLabs regarding the trackability and detectability of the satellites is attached as a separate exhibit. *See* Exhibit C: LeoLabs Report.

32 *Id.*

33 *See* NASA-STD-8719.14A, Process for Limiting Orbital Debris, Requirement 4.3-1a (2019).

34 *See* 47 C.F.R. § 25.121(a)(1).

any Swarm satellite is rendered inoperative, it will always passively de-orbit. The de-orbit completes within 5 years of launch in the average case, and 7.9 years in the worst case.

Swarm satellites are able to use the onboard magnetorquer to maneuver into a low-drag or high-drag state (see Figure 4, below). If a functional Swarm satellite is commanded to de-orbit faster, it can be commanded to enter a high-drag mode and deorbit more quickly than the nominal orbital lifetime of 5 years.

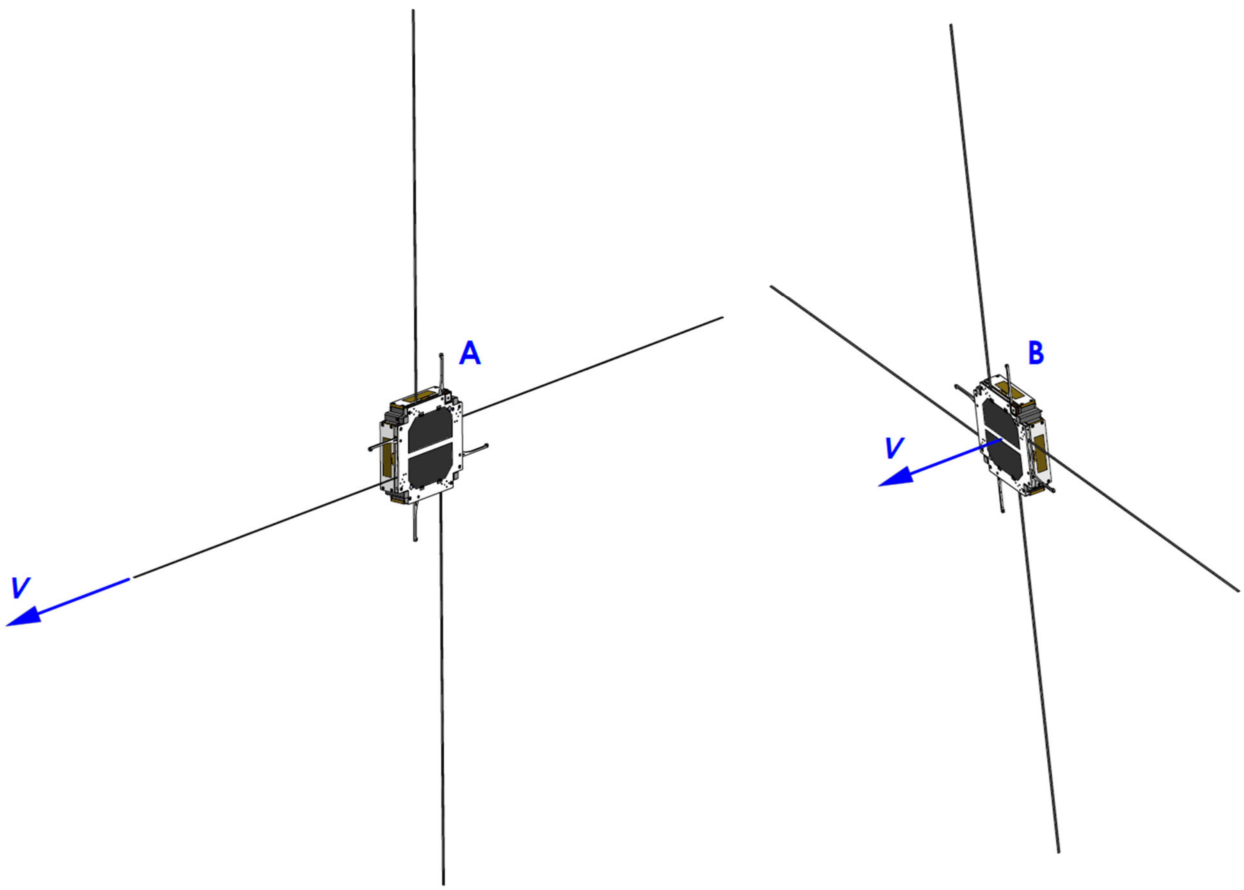

Figure 4. Flight configurations for a Swarm satellite, where "v" represents the velocity vector. (A) A Swarm satellite in the low-drag flight configuration. (B) A Swarm satellite in high-drag flight configuration to de-orbit more rapidly.

4) Post-Mission Disposal Plans

With respect to the post-mission disposal plan, Swarm has chosen an altitude of 300 km as the end of life altitude. This altitude is stable for the Swarm satellites for approximately 1 to 3 months before a passive atmospheric re-entry occurs. At 300 km, the propellant reservoir will be emptied, and the onboard lithium ion battery will be put into a discharge state, and the transmitter will be commanded to cease all transmissions.

Swarm has conducted a risk analysis using NASA's DAS tool to assess spacecraft re-entry hazards. As described in greater detail in the attached ODAR, none of the components of the Swarm spacecraft will survive re-entry and reach the surface of the Earth. Swarm is therefore fully compliant with the casualty probability requirements, which requires a probability of less than 1/10,000.

D. NVNG MSS Requirements: § 25.142(a)

1) Demonstration of Non-Interference

As explained in more detail below, none of the proposed modifications would affect Swarm's ability to prevent harmful interference with existing operations. The power flux density at the Earth's surface from Swarm's downlink transmissions in the 137.0–138.0 MHz band will not exceed -125.0 dBW/m^2/4kHz, and emissions into the 150.05–153.00 MHz radio astronomy service band will not exceed -259.0 dBW/m^2/Hz. Furthermore, the spectrum mask for Swarm emissions will continue to comply with the limits set forth in Section 25.202(f) of the Commission's rules. Finally, Swarm can share effectively with the only other NVNG MSS system authorized to operate in VHF and will continue to protect Federal operations through coordination.

2) Power Flux Density

Swarm's proposed downlink (space-to-Earth) operations will be conducted in the 137.0–138.0 MHz band. Section 25.142(a)(2) of the Commission's rules requires Swarm to identify the power flux density produced at the Earth's surface by each space station in the system to allow determination of whether coordination with terrestrial services is required.

Swarm proposes to deploy its constellation of technically identical satellites in orbits with altitudes of 300–585 km. Natural orbital altitude degradation will occur over time, resulting in Swarm satellites operating at altitudes below 400 km. The minimum operational altitude at which a Swarm satellite will transmit is 300 km. Power flux density calculations were therefore conducted for a satellite operating at orbital altitudes of 300 km, 400 km, 500 km, and 585 km to reflect the range of potential power flux density values.

Power flux density values for a Swarm satellite as a function of elevation angle are specified below in Table 6 and Figure 5.[35] The power flux density values shown in Table 6 were calculated using the following parameters:

- Necessary bandwidth: 20.8 kHz
- Transmitter power: 1.5 W
- Maximum antenna gain: see Table 6
- Orbital altitude: 300, 400, 500, or 585 km
- Bandwidth of interest: 4 kHz

		Maximum PFD (dBW/m²/4kHz)			
Elevation angle	**Max. Gain (dBi)**	**300 km orbit**	**400 km orbit**	**500 km orbit**	**585 km orbit**
0-5°	-3.5	-143.4	-145.0	-146.2	-147.1
5-10°	-3.4	-141.1	-143.0	-144.4	-145.4
10-15°	-3.3	-139.0	-141.1	-142.6	-143.7
15-20°	-3.1	-137.1	-139.3	-141.0	-142.2
20-25°	-2.8	-135.1	-137.8	-139.5	-140.7
25-90°	0.0	-125.9	-128.4	-130.4	-131.7

Table 6. Power flux density values as a function of elevation angle.

[35] The power flux densities provided below represent a worst-case (highest PFD) scenario. The PFD values do not account for additional real-world losses that will result in further attenuation of the PFD level at the Earth's surface.

The ITU specifies that space stations transmitting in the 137.0–138.0 MHz band require coordination with terrestrial services only if the PFD produced by the space station exceeds -125.0 dBW/m^2/4kHz at the Earth's surface.[36] As shown in Table 6 and Figure 5, transmissions from Swarm satellites will not exceed this threshold in any angle of arrival for any operational altitude. In addition, the PFD limits specified in Section 25.208 are not applicable to the 137.0–138.0 MHz band.

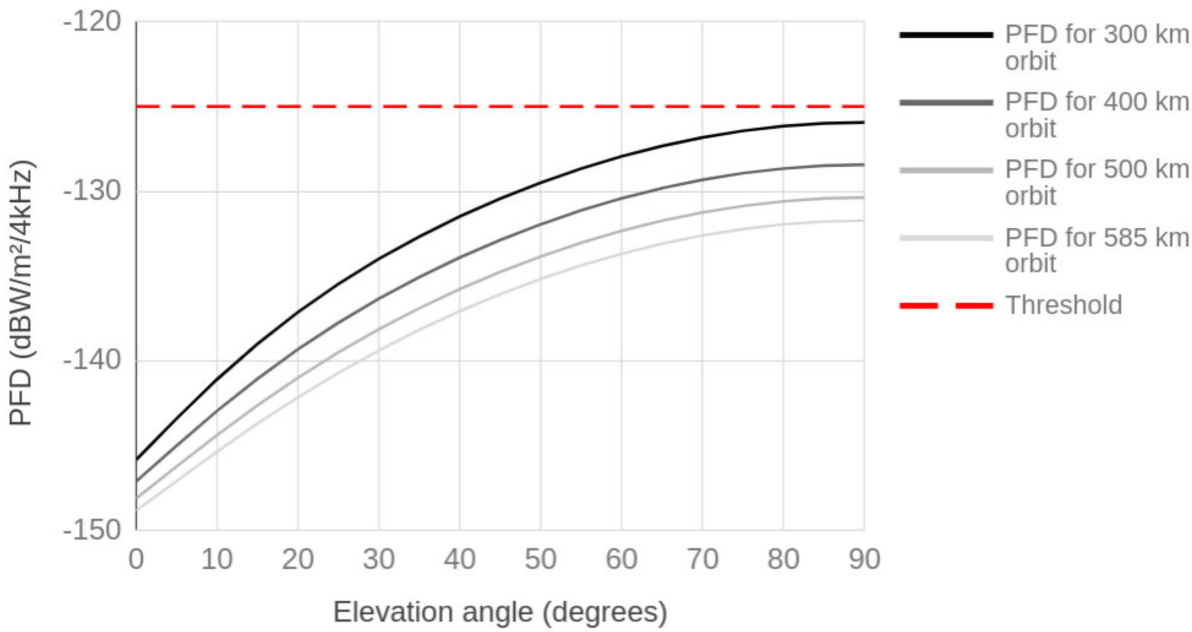

Figure 5. Power flux density at the Earth's surface as a function of elevation angle for representative satellite orbit altitudes.

3) Radio Astronomy Protection

Section 25.142(a)(2) of the Commission's rules requires Swarm to identify measures employed to protect the radio astronomy service ("RAS") in the 150.05–153.00 MHz band. Swarm's satellites transmit only in the 137.0–138.0 MHz band, and out-of-band emissions are minimized by a combination of digital modulation techniques and filtering. These factors result in

36 *See* 47 C.F.R. § 2.106 at International Footnote 5.208; ITU R.R., Appendix 5, Annex 1 ¶ 1.1.1.

at least 100 dB spectral roll-off in the 150.05–153.00 MHz band, resulting in a power flux density at Earth's surface not exceeding -261.9 dBW/m^2/Hz for the worst case scenario of a 300 km orbital altitude, thereby meeting the radio astronomy service protection criteria specified by the ITU of -259.0 dBW/m^2/Hz (see Table 7).[37]

Table 7. Calculation of out-of-band emissions from the Swarm system into the RAS band.

Out-of-Band Emissions into Radio Astronomy Services Band (150.05–153.00 MHz)	
Maximum EIRP (W)	1.50
Maximum EIRP (dBW)	1.76
Necessary Bandwidth (kHz)	20.8
Maximum PFD (dBW/m²/4kHz)	-125.9
Bandwidth Conversion	-36
Maximum PFD (dBW/m²/Hz)	-161.9
Spectrum Roll-off Mask in RAS Band (dBc/m²/Hz)	-60
System Filtering in RAS Band (dBc/m²/Hz)	-40
Power Density in RAS Band (dBW/m²/Hz)	-261.9
RAS Protection Criteria (dBW/m²/Hz)	-259.0

4) Emission Limitations

The spectrum masks for a representative downlink transmission from a Swarm satellite is shown in Figure 6. This spectrum mask demonstrates that Swarm's satellites comply with the out-of-band emission limitations specified in Section 25.202(f) of the Commission's rules. In addition, the carrier frequency of each Swarm satellite will be maintained within 0.002% of the reference frequency as required by Section 25.202(e) of the Commission's rules.

37 *See* 47 C.F.R. § 2.106 at International Footnotes 5.208A and 5.208B; ITU R.R. Res. 739 (Rev. WRC-15) and Recommendation ITU-R M.1583. As specified in ITU-R M.1583, the protection criteria is -238 dBW/m^2 in a 2.95 MHz reference bandwidth, and as recommended in ITU-R RA.769-2 Table 1, the threshold for harmful interference is -259.0 dBW/m^2/Hz at a center frequency of 151.525 MHz.

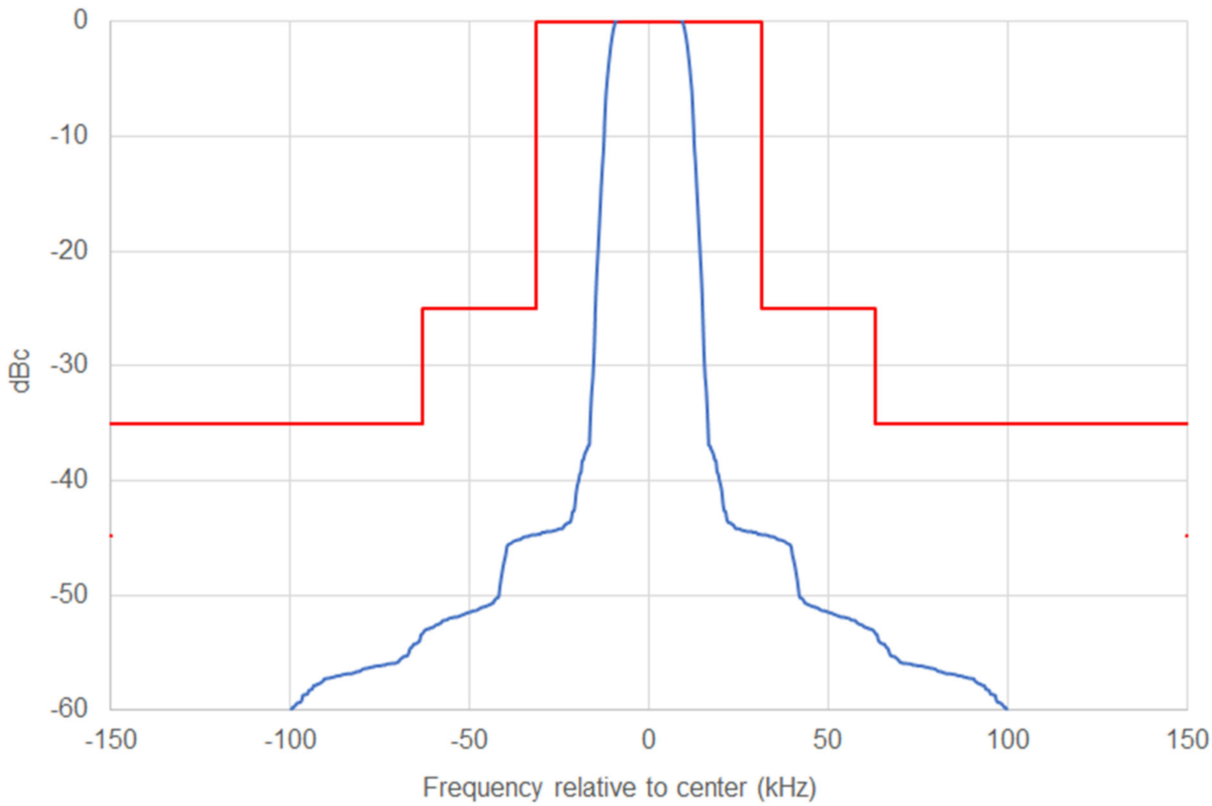

Figure 6. Spectrum mask for an example Swarm emission, in this case a 41.7 kHz emission.

5) Limits on Re-Transmission of Signal

Swarm's satellites comply with the requirement specified in Section 25.142(a)(3)(ii) of the Commission's Rules that no signal received by satellites from sources outside of the system shall be retransmitted with a PFD level exceeding the limits specified in Section 25.142(a)(2). Swarm's satellites employ onboard processing and do not utilize "bent-pipe" transponders. Signals received by a satellite that originate from Swarm user terminals and ground stations are demodulated and processed. An appropriate response is then generated, modulated, and transmitted by the satellite. Unknown or incompatible signals received by a satellite are ignored and do not result in a transmission response, ensuring that signals originating from sources outside of the Swarm network are not re-transmitted.

E. Operating Conditions and Coordination: § 25.142(b)

1) No Voice Services

Swarm will not be providing voice services with its satellite constellation.

2) Coordination with Federal Government Users

Section 25.259 of the Commission's rules requires non-voice, non-geostationary satellite systems in the 137.0–138.0 MHz band to time share with National Oceanic and Atmospheric Administration ("NOAA") meteorological satellite operations. Swarm has reached a coordination agreement with NOAA regarding restriction of transmissions into the "protection area" of the NOAA satellites described in Section 25.259(a) with respect to its existing authorization and will work with NOAA to ensure continued protection under the new operating parameters sought herein. Importantly, Swarm and NOAA successfully coordinated even though many of Swarm's existing assignments overlap with NOAA downlink channels. Swarm is confident it can continue to protect NOAA operations upon grant of this application, which will make additional, non-overlapping VHF frequencies newly available for Swarm satellite transmissions. In addition, Swarm has provided NOAA with a point of contact who will be available twenty-four hours per day, seven days per week to expeditiously address and resolve interference reports as required by Section 25.259(b). Each Swarm satellite is programmed to automatically turn off and cease transmission if no signal is received from a Swarm earth station after 72 hours, in compliance with Section 25.259(c).

Moreover, as contemplated by Section 25.142(b)(2)(ii), Swarm will provide any additional information requested by the Commission required for coordination of the satellite system with other Federal Government users through the Interdepartment Radio Advisory Committee (IRAC) process.[38]

3) Coordination with previously licensed NVNG MSS Systems

The only other existing NVNG MSS VHF licensee is ORBCOMM. Frequencies assigned to ORBCOMM on a primary basis were always intended to be shared with other NVNG MSS systems, and the Commission's existing rules explicitly require ORBCOMM to coordinate with new systems pursuant to Section 25.142(b)(3).[39] Consistent with the Commission's NVNG MSS service rules, Swarm is willing to coordinate its proposed frequency usage with ORBCOMM to prevent harmful interference and ensure efficient use of the limited NVNG MSS radio spectrum.

Swarm believes that a combination of sharing strategies will enable it to share spectrum effectively with ORBCOMM, especially given the comparatively low power (and low power density) of Swarm's transmissions in any given direction. For example, Swarm uses Carrier-Sense Multiple Access media access control protocol with Collision Avoidance (CSMA/CA), which employs a "listen-before-talk" protocol to verify the absence of other traffic before transmitting on a given channel. Swarm can also share channels by using time-division multiple access (TDMA) and by implementing geographic sharing techniques. Moreover, with access to more

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38 *See* 47 C.F.R. § 25.142(b)(2)(ii).

39 *See* 47 C.F.R. § 25.142(b)(3) (directing applicants and existing licensees to "cooperate fully" in coordination efforts); *See generally* A*mendment 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*, Report and Order, 13 FCC Rcd. 9111 (1997); *Applications of ORBCOMM License Corp*., Order and Authorization, 23 FCC Rcd. 4804 ¶¶ 22-23 (Int'l Bur., Office of Eng'g and Tech. 2008).

VHF MSS frequencies, Swarm will have additional flexibility to avoid active channels and thus deconflict operations without compromising network performance.

F. Construction Milestones: § 25.164

All of Swarm's three hundred (300) satellites will be constructed and launched within the milestone schedule specified in Section 25.164(b)(1) of the Commission's rules.

G. Cessation of Emissions: § 25.207

Each Swarm satellite can be turned off upon telecommand from a Swarm ground station. This ensures definite cessation of emissions as required by Section 25.207 of the Commission's rules. Each Swarm satellite has a hardware and software watchdog timer that resets the satellite if the satellite enters an anomalous condition or is subject to an upset from radiation (total ionizing dose or single event upset). Each Swarm satellite is also programmed with a 72-hour "dead-man's switch," which turns the satellite off every 72 hours. Each Swarm satellite must receive a "heartbeat" command from a Swarm earth station once every 72 hours to remain on and continue transmitting.

III. PUBLIC INTEREST BENEFITS

With its recently granted space- and ground-segment authorizations, Swarm stands on the cusp of launching a state-of-the-art network that will empower end users to send and receive data anywhere in the world at a fraction of the cost of comparable existing satellite services. But while Swarm always anticipated significant demand for its services, the response it has received since initially designing its constellation has been nothing short of remarkable. Companies operating across numerous industry verticals—and U.S. government clients alike—have expressed an urgent need for a low-cost, satellite communications medium capable of reaching underserved or unserved rural areas in the United States and around the world.[40] Swarm stands ready to meet those needs—but will be able to do so for more users and types of services, with improved sharing capabilities, if the Commission grants this amendment. The modifications Swarm seeks also will help drive competition between satellite platforms, improving price and quality of service for a large variety of satellite consumers.

Commercial demand. Swarm already has relationships with Fortune 100 companies and other prominent U.S. businesses—and continues to see commercial interest in its flexible, low-cost platform expand. For example, Swarm is working with a top automaker and other transportation companies to address connected car, trucking, and fleet monitoring use cases, leveraging its ability to provide connectivity to small, low-power ground devices ideally suited to track mobile vehicles and equipment (in addition to static assets). Operators in the maritime industry likewise have expressed strong interest in Swarm's low-cost solutions for container tracking, crew communications, emergency response, and port operation activities.

Large agribusinesses and small precision agriculture technology startups are also working with Swarm to improve productivity by deploying satellite-enabled sensors throughout U.S. farmland. As Chairman Pai recently explained at the Second Annual Space Summit, Swarm's satellite connectivity "will enable farmers to have sensors where there is no cell coverage, supporting new precision agriculture applications."[41] The Commission elsewhere has acknowledged the significance of precision agriculture,[42] which has improved overall crop

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[40] Swarm's proposed constellation supports narrowband communications, including basic Internet connectivity (e.g., downloading a Wikipedia page), text messaging, and various M2M and IoT applications.

[41] *See* Ajit Pai, Chairman, FCC, Remarks at the "LAUNCH: The Space Economy" Summit (Dec. 3, 2019), https://docs.fcc.gov/public/attachments/DOC-361140A1.pdf.

[42] *See, e.g.*, *FCC Announces the Establishment of the Task Force for Reviewing Connectivity and Technology Needs of Precision Agriculture in the United States and Seeks Nominations for Membership*, Public Notice, DA 19-568 (rel. June 17, 2019).

productivity in the U.S. by 15% in recent years, providing a competitive edge to U.S. farmers.[43] Given that existing satellite data services are prohibitively expensive, however, the deployments necessary to support these endeavors are often restricted to the geographic footprint of terrestrial networks. That state-of-affairs will change with the launch of Swarm's network, unleashing new unmet demand in this important sector.

Swarm continues to develop additional commercial applications based on interest from corporate clients. These applications include pipeline monitoring, asset tracking, equipment diagnostics, weather monitoring, animal tracking, disaster detection, remote backhaul, scientific research, and emergency response services. Much like the Commission, Swarm also sees growth opportunities to serve healthcare patients. Indeed, drawing attention to pilot programs in Louisiana and Mississippi, the Commission recently extolled the public interest benefits of remote patient monitoring in medically underserved areas, noting the dramatic improvements in health outcomes made possible when medical professionals can track blood pressure and other patient parameters from a distance.[44]

Public sector demand. Swarm can support M2M and personnel communications that aid a variety of U.S. government missions, including border patrol, defense, and homeland security. As a result, Swarm continues to see interest in using its network for national security operations, and remains engaged with U.S. government organizations seeking to strengthen our communications resiliency domestically and around the world. In a testament to this potential, Swarm was recently named as 1 of 21 companies tentatively selected to receive a Strategic Financing ("STRATFI")

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43 *See* Kurt Marko, FORBES, *Precision Agriculture Eats Data, CPUC Cycles: It's a Perfect Fit for Cloud Services* (Aug. 25, 2015), http://www.forbes.com/sites/kurtmarko/2015/08/25/precision-ag-cloud/.

44 *See Promoting Telehealth for Low-Income Consumers*, Notice of Proposed Rulemaking, WC Docket No. 18-213, ¶ 11 (rel. July 11, 2019) (discussing pilot programs in Louisiana and Mississippi).

contract through a program administered by AFVentures,[45] the umbrella organization for the Air Force's efforts to work with small businesses to fund critical technologies for the warfighter.[46] Swarm's potential national security impact also has been recognized in two Small Business Innovation Research ("SBIR") grants from the U.S. Air Force,[47] while two additional SBIR grants awarded by the National Science Foundation have recognized Swarm's broader societal potential.[48]

Demand from NGOs, humanitarian efforts, and U.S. and global development initiatives. Swarm also sees demand for applications that are vital to U.S. and global development initiatives, and from non-governmental organizations, nonprofits, and humanitarian organizations that serve regions with poor communications infrastructure in the United States and abroad. Swarm can help these organizations advance their missions through the deployment of IoT devices that monitor air and water quality, facilitate emergency communications, and track vital weather and climate changes, and by expanding the reach of text message platforms to individuals in locations without terrestrial coverage. As one example, Swarm has already partnered with SweetSense, a U.S.-based company providing remote sensors for the global development sector. SweetSense plans to use Swarm's network for projects in the United States and worldwide, including by monitoring groundwater resources for farmers in California and tracking the function of water pumps in East Africa to ensure uninterrupted access to clean drinking water.

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45 AFVentures is a collaboration between the Air Force Small Business Innovation Research and Small Business Technology Transfer Program, AFWERX and Air Force Acquisitions.

46 *See* Jennifer-Leigh Oprihory, *Roper Unveils AFVentures, Announces Nearly $1B in Small Business Contracts,* AIR FORCE MAGAZINE (Mar.18, 2020), https://www.airforcemag.com/roper-unveils-afventures-announces-nearly-1b-in-small-business-contracts/; *See also,* Press Release, U.S. Air Force, Air Force Pivots to Virtually Connect Defense Innovators, Announces 'Big Bets' (Mar. 13, 2020), https://www.af.mil/News/Article-Display/Article/2111607/air-force-pivots-to-virtually-connect-defense-innovators-announces-big-bets/.

47 *See* SBIR Award contract numbers Phase I: FA875119PA053 and Phase II: FA864919CA010.

48 *See* NSF Award Nos. 1647553 and 1758752.

Grant of this application will better equip Swarm to address this significant and rapidly expanding demand for global, low-cost connectivity. With additional satellites in its constellation, Swarm will be able to serve more users while maintaining network performance, and to support additional customers with large fleet operations or who seek to implement satellite connectivity into widely distributed consumer goods. It will also help Swarm accommodate requests for dedicated capacity on board Swarm space stations. Likewise, with access to more MSS spectrum, Swarm will see a near 1-to-1 improvement in throughput and number of users supported, allowing consumers and business customers to fully leverage the benefit of rapidly developing IoT, M2M, and messaging technologies. Moreover, as explained in more detail below,[49] a limited waiver of footnote US323 will expand and diversify the range of data-driven applications that Swarm can support in the marketplace.

Importantly, the modifications sought in this amendment will provide Swarm with the flexibility it needs to fulfil demand while also sharing effectively with other users. With a larger constellation and access to more VHF channels, Swarm can better utilize satellite and frequency diversity to avoid harmful interference into other licensed commercial and government systems.

Finally, enhanced competition has always been one of the most significant public interest considerations for Swarm's constellation—and grant of the application will continue to advance that important objective. Although other satellite operators presently provide data services that in some ways are technically comparable to Swarm's offerings, these operators employ older network architectures dependent on massive on-orbit platforms, creating significant cost-effectiveness hurdles that place many IoT and M2M applications—and remote communities—simply out of reach. With a more robust and more capable network built with state-of-the-art small satellite

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[49] *See* Section V, *supra.*

technology, Swarm can both satisfy unmet needs for low-cost connectivity and drive cost and quality improvements across satellite platforms, including those built using traditional aerospace and satellite technology.

IV. 47 U.S.C. § 304 WAIVER

Swarm Technologies, Inc. hereby waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

V. LIMITED WAIVER OF FOOTNOTE US323

To carry out its well-established "obligation to seek out the 'public interest' in particular, individualized cases,"[50] the Commission may waive its rules "on its own motion or on petition if good cause therefore is shown."[51] To show good cause, a petitioner may demonstrate that enforcement of the rule is not necessary to serve the rule's purpose, and that a waiver would serve the public interest.[52] When reviewing Commission decisions, courts have recognized that a rule "may not be in the 'public interest' if extended to an applicant who proposes a new service that will not undermine the policy[] served by the rule."[53] The Commission will also consider "hardship, equity, or more effective implementation of overall policy" on an individual basis to reach the right result in particular cases.[54]

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50 *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).

51 47 C.F.R. § 1.3.

52 *See WAIT Radio*, 418 F.2d at 1153. *See also Northeast Cellular Telephone Co. v. FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990) (waivers are appropriate where special circumstances "warrant a deviation from the general rule and such deviation will serve the public interest.").

53 *WAIT Radio* at 1157.

54 *Id.* at 1159.

To protect terrestrial government users,[55] footnote US323 to the U.S. Table of Frequency Allocations restricts Earth-to-space transmissions from individual mobile earth stations operating in the 148.0–149.9 MHz band. Assuming the mobile earth station avoids frequencies actively being used by terrestrial systems (which Swarm's terminals would do), the footnote requires the station to observe a duty cycle of 1% within any 15-minute period, a maximum transmission duration of 450ms, and a wait time of 15 seconds between consecutive transmissions on the same frequency.[56] Even for narrowband IoT, M2M and messaging services, the limitations posed by these parameters are significant; indeed, packet data alone can consume a significant portion of the maximum permitted duration at typical throughputs achievable in VHF. On the other hand, by layering a very short maximum duration and a very long wait period *on top* of a very low duty cycle and the mandatory use of active channel avoidance, the rule provides a level of protection to terrestrial government operations that is much greater than necessary. Calibrated carefully, a waiver would unleash new services in 148.0–149.9 MHz without any impact on federal use of the band.

To expand and diversify the services supported by the Swarm system—while fully meeting the diverse needs of terrestrial systems that operate in VHF—Swarm seeks a partial waiver that would extend the maximum permissible duration and relax the minimum wait time requirement, while continuing to require Swarm to comply with a 1% duty cycle and avoid transmitting on active frequencies. Specifically, Swarm requests authority for individual mobile earth stations communicating with its constellation in the 148.0–149.9 MHz band to transmit for a duration of

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[55] *See Amendment of Section 2.106 of the Commission's Rules to Allo-cate Spectrum to the Fixed-Satellite Service and the Mobile-Satellite Service for Low-Earth Orbit Satellites*, Report and Order, 8 FCC Rcd. 1812 ¶¶ 16, 20 (1993).

[56] *See* 47 C.F.R. § 2.106 at footnote US323.

up to 1700ms without a minimum wait time, so long as each terminal observes a 1% duty cycle within any 15-minute period and avoids frequencies actively being used by Federal terrestrial systems.

Grant of the waiver would ensure that US323 fully satisfies its intended objective of protecting federal terrestrial systems without unnecessarily impeding Swarm's satellite service. Given the nature of terrestrial deployments, it is unlikely that Swarm user terminals will produce interference even when terrestrial devices transmit or receive on the same frequencies and at the same time as a transmitting Swarm user terminal. With active channel avoidance and a very low duty cycle, this already low risk of detectable interference would diminish considerably—to say nothing of the even lower risk of harmful interference. Moreover, in the extraordinarily unlikely event that a terrestrial system experiences such interference, the 1700ms maximum transmission duration would continue to provide backstop protection by ensuring that affected communications are only minimally disrupted. Swarm has started and will continue to work with the National Telecommunications and Information Administration (NTIA) and federal users to demonstrate that their operations will remain protected under the parameters sought in this waiver request. Swarm will update the Commission on the outcome of those discussions as appropriate.

Grant of the waiver would serve the public interest. At no cost to incumbent terrestrial use of the band, the waiver would provide Swarm with additional capacity to support low-cost narrowband data services that require larger packet sizes to relay an acceptable amount of information from individual devices. More consumers in unserved or underserved areas would benefit from a richer messaging experience and even basic Internet access. In addition, the greater uplink throughput available using Swarm devices in the 148.0–149.9 MHz band would drive innovation across a variety of M2M and IoT applications, from health monitoring to precision agriculture to connected vehicles. Importantly, federal users themselves would stand to benefit from a waiver that continues to protect their terrestrial operations given the many applications of global, low-cost satellite connectivity of potential interest to the U.S. government.[57]

Swarm notes that, while the Commission typically addresses compliance with technical rules governing earth-to-space operations in ground-segment applications, it nevertheless "include[d] a condition" in Swarm's space station authorization "requiring Swarm's transmit earth station operations to comply with the Footnote US323."[58] It did so even though it "agree[d] with Swarm" that "concerns regarding Swarm's compliance with footnote US323 are premature" and ought to be addressed "in the context of [Swarm's] earth station applications."[59] Thus, if the Commission grants the waiver, Swarm respectfully requests that it implement relief by eliminating the condition from Swarm's space station authorization and modifying the corresponding condition in Swarm's blanket earth station authorization to reflect newly permissible parameters of operation.[60]

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57 *See infra* nns. 45-48 & accompanying text (discussing Swarm's recently awarded U.S. government grants).

58 *Swarm Grant* ¶ 11.

59 *Id.*

60 Swarm will apply promptly for the same waiver in an application to modify its blanket earth station authorization.

VI. ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

<u>/s/ Kyle Wesson</u>
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