Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

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

APPLICATION FOR MODIFICATION

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APPLICATION FOR MODIFICATION

Pursuant to Section 25.117 of the Commission's rules, Swarm Technologies Inc. ("Swarm") requests a modification of its license to operate a non-voice, non-geostationary ("NVNG") satellite system in the mobile-satellite service ("MSS") in the Very High Frequency ("VHF") bands.[1] Swarm seeks authority to implement onboard propulsion (and slightly increase the mass of its satellites to support the new propulsion system), replace passive Ku-band retro-reflectors with GPS antennas, and operate at a slightly wider range of orbital altitudes. If granted by the Commission, these modifications would allow Swarm to deploy services more rapidly and enhance the space safety profile of its constellation without affecting other operators. Swarm urges the Commission to grant the application expeditiously.

I. INTRODUCTION AND SUMMARY

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 satellites. Even as Swarm continues to advance its plans to launch commercial service later this year, it has been busy developing new capabilities for its unique small satellite network.

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1 *See Application of Swarm Technologies, Inc.*, Memorandum Opinion, Order and Authorization, 34 FCC Rcd. 9469 (Int'l Bur. 2019). *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).

In response to anticipated changes to the Commission's orbital debris mitigation rules,[2] Swarm developed a novel active propulsion system that requires only a modest increase in mass and no change to the 1/4U form factor of a Swarm satellite. Swarm also developed a custom-built GPS antenna to replace the Ku-band retro reflectors featured on its existing design, a change that will further improve the trackability of Swarm satellites. While Swarm plans to begin launching space stations that conform to its existing authorization, it seeks the flexibility to implement these design changes to satellites in its constellation as soon as possible. Swarm understands that active propulsion may soon become mandatory and will ensure that all satellites launched after the effective date for such a rule meet the requirement.

As a rideshare customer on the cusp of its first commercial launch, Swarm also has discovered that a modest increase in orbital range flexibility would drive a significant improvement in Swarm's ability to pursue launch opportunities on a schedule that adheres more closely to its readiness to deploy. While Swarm's existing satellite license allows it to operate at altitudes ranging from 300 km to 550 km (and to deploy at altitudes ranging from 400 km to 550 km), a significant number of commercial launches with available secondary payload capacity deploy at altitudes ranging just above 550 km (and in some cases under 400 km). Swarm thus seeks authority to deploy and operate at altitudes between 300 km to 585 km altitude so that it can reach full capacity and full coverage more quickly, and deliver low-cost data services as soon as possible. The modest additional flexibility that Swarm seeks would pose no spectral interference or debris risk. Swarm is already licensed to transmit down to 300 km, and the shift from 550 km to 585 km would not materially affect the lifetime probability of collision for a Swarm satellite (which

[2] *See Mitigation of Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking, IB Docket No. 18-313 (rel. Apr. 24, 2020) ("*Orbital Debris Update Order*"); *Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking, 33 FCC Rcd. 11352 ¶ 34 (2019).

remains less than 4e-7 in a maximum-lifetime scenario) nor the risk of a conjunction with other large LEO systems (many of which operate above 585km). In any event, Swarm's collision avoidance and rapid de-orbit capabilities—which active propulsion will only enhance—mitigate any such risk.

Table 1 below summarizes the modifications sought in this application. Swarm certifies that information other than items specified in this application has not changed.

Modifications to Swarm's Existing Space Station Authorization		
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 1. Modifications to Swarm's Existing Space Station Authorization

Grant of the application will serve the public interest by allowing Swarm to deploy services more quickly while promoting a safer space environment. Swarm's innovative active propulsion system will provide additional maneuverability, facilitate the movement of Swarm satellites into their designated orbits, help Swarm deconflict orbital operations with other systems, and improve Swarm's existing rapid de-orbit capabilities, all of which will enhance the already low-risk safety profile of the Swarm constellation. The additional mass will accommodate the propulsion system. Moreover, because the trackability of Swarm's satellites in no way depends on the availability of Ku-band radar, removing the Ku-band retro reflectors will only improve tracking of Swarm's constellation: with the additional satellite surface area made available, Swarm can install custom-built GPS antennas to enable precise, real-time tracking of its satellites on orbit.

II. DESCRIPTION OF MODIFICATIONS

A. Propulsion and Mass

Swarm is licensed to operate a constellation of 150 satellites in low Earth orbit (LEO). Swarm's licensed satellites have a total mass of up to 0.45 kg and a 1/4U cubesat form factor (excluding deployable antennas).[3] As currently designed, Swarm's satellites can effectively use passive stabilization for coarse pointing[4] and a magnetorquer assembly for higher-precision pointing. Through differential drag, this passive system can accelerate disposal and even perform collision avoidance maneuvers.

To further improve the maneuverability of its satellites—and comply with anticipated orbital debris requirements[5]—Swarm recently developed a safe, reliable, and high-performing

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3 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.

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

5 *See Orbital Debris Update Order* ¶ 164 (proposing to require propulsion-based maneuverability above certain orbits in low Earth orbit).

active propulsion system. The dual-mode system leverages the benefits of cold gas and electric propulsion to maintain the small 1/4U form factor critical to Swarm's deployment model, while providing enough impulse to perform station keeping, spreading, collision avoidance maneuvers, and aid in post-mission disposal. As explained in the attached Orbital Debris Assessment Report ("ODAR"),[6] Swarm uses a non-toxic green propellant and has taken steps to prevent (and mitigate any potential damage from) over-pressurization. Because the propellant exists as a gas in a vacuum, its release presents no concern over persistent droplets or persistent solids. Swarm is also working with a number of range safety groups, including the U.S. Air Force 30th Space Wing as well as multiple private commercial groups, to ensure that the propulsion system is compatible with launch safety procedures.

Due primarily to the need to store propellant, the mass of each satellite will increase. Swarm accordingly notes that, at the upper limit, the mass of a Swarm satellite may reach 0.6 kg.

B. Removal of Ku-band passive retro-reflectors

The satellites described in Swarm's initial space station application are equipped with four passive radar reflectors optimized for space observation radars operating in the Ku-band. As Swarm previously explained, however, the trackability of Swarm satellites in no way depends on the availability of Ku-band radar, let alone the use of passive reflectors to increase the radar cross-section (RCS) of a Swarm satellite in Ku-band.[7] Because Swarm satellites utilize deployable antennas that extend to many multiples of its length once in orbit, Swarm satellites are just as trackable—if not more trackable—than satellites four times the size by many different types of ground systems (see Figure 1 below). As a result of these deployable antennas, LeoLabs reported

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[6] *See* Exhibit A.

[7] See Letter from Kalpak Gude, General Counsel, Swarm Technologies, Inc., to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-LOA-20181221-00094 (filed May 28, 2019).

that "the RCS of the [Swarm satellites is] approximately twice the RCS of one of the 1U satellites," and had no issue tracking Swarm satellites without the use of Ku-band imaging.[8] A separate, detailed analysis of the trackability of Swarm's 1/4U satellites 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.[9] Thus, if a standard 1U satellite is sufficiently trackable, as the Commission recently presumed,[10] so too is a Swarm satellite—with or without Ku-band retro-reflectors.[11]

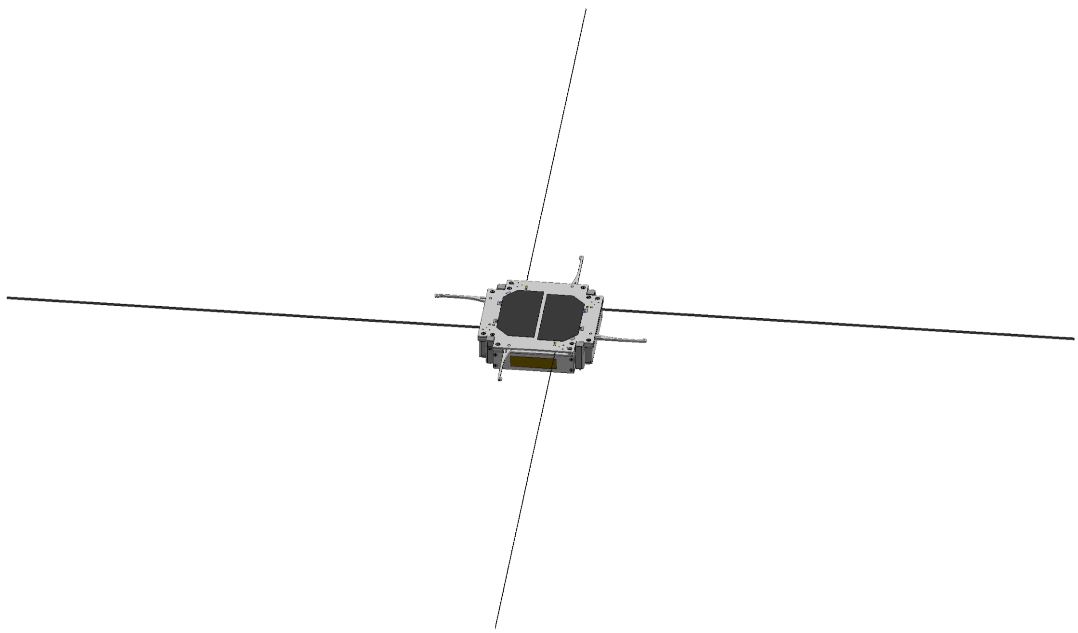

Figure 1. A CAD rendering of the Swarm satellite (antennas are cropped in this rendering). Antennas are 108 cm from tip to tip and are released once in orbit.

Swarm thus believes that the scarce surface area consumed by the Ku-band retro-reflectors can be put to better use and has developed custom-built GPS antennas to take their

8 A copy of the trackability analysis conducted by LeoLabs, which Swarm previously provided with its initial space station application, is attached as Exhibit C.

9 A copy of that analysis is attached as Exhibit B.

10 *See Orbital Debris Update Order* ¶ 58 (presuming that a 1U satellite is trackable); *see also id.* ¶ 58 & n. 187 (noting that "deployable components" can "enhance trackability").

11 *See id.* ¶ 62 (declining to adopt "any rule that would specify a particular type of tracking technology").

place on the satellite's exterior. With these antennas, GPS-based tracking systems will be able to follow Swarm satellites with much improved accuracy, enabling precise, real-time tracking of Swarm's constellation in orbit and increasing opportunities to coordinate with other operators to avoid conjunctions.

Swarm's space station license does not condition Swarm's operations on the continued use of Ku-band retro reflectors. Nevertheless, due to the Commission's interest in ensuring that small satellite systems remain trackable, Swarm seeks approval of the design change to the extent required by the Commission.

C. Altitude range of 300 km to 585 km

In its initial application, Swarm sought authority to operate at altitudes between 300 km and 550 km and to deploy at altitudes between 400 km and 550 km. However, as a secondary payload customer, Swarm remains subject to launch schedule postponements and orbital parameter changes dictated by launch providers and over which Swarm has no control. To expand the launch opportunities available to Swarm, for both initial deployments and subsequent replenishments, Swarm requests authority to deploy and operate at altitudes between 300 km to 585 km. Although limited in scope, this additional flexibility will allow Swarm to reach full capacity and full coverage at a more rapid pace, and ultimately serve more users in more places more quickly.

The modification Swarm seeks will not affect the spectral interference characteristics of the Swarm constellation. Swarm's satellites are *already* licensed to transmit down to 300 km, and whether they do so immediately upon deployment or near the end of their mission is irrelevant to the emissions produced by the network. In its application, Swarm already calculated power flux density levels ("PFD") at the Earth's surface for a representative range of spacecraft altitudes, including the worst-case scenario of transmission from an altitude of 300 km. As shown in Table

2 below, proposed emissions at 300 km will still remain below the -125.0 dbW/m²/4kHz PFD limit specified by the ITU above which coordination with terrestrial services would be required.[12] And at 585 km rather than 550 km, they demonstrate only that terrestrial systems will remain protected by an even greater margin.

		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 2. Power flux density values as a function of elevation angle.[13]

Nor will increasing permissible orbital altitudes from 550 km to 585 km affect the space safety profile of the Swarm system. As an initial matter, Swarm plans to use its maneuvering capabilities, including its magnetorquer system and propulsion system, for collision avoidance, and to ensure its satellites do not exceed 585 km in altitude. Moreover, at 585 km, Swarm satellites still would be launched to a lower altitude than satellites operated by ORBCOMM, Iridium, and Globalstar, and the orbits proposed by Myriota,[14] Hiber,[15] and Amazon's Kuiper program.[16] They

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

[13] PFD values were calculated using the necessary bandwidth (20.8 kHz) to account for the worst-case (highest PFD) scenario.

[14] *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).

[15] *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).

[16] *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).

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.[17] 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.[18] 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.

Even accounting for a slightly longer de-orbit from 585 km, the collision risk of a Swarm satellite remains exceedingly low. As shown in the attached ODAR, the Swarm system would remain compliant with all applicable NASA orbital debris requirements with the changes sought in this application.[19] Specifically, 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 Debris Assessment Software version 3.0 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. And, again, Swarm satellites can use the onboard magnetorquer to maneuver into a low-drag or high-drag state (see Figure 2, below). Thus, upon command, a functional Swarm can enter a high-drag mode and de-orbit more quickly than its

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17 *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).

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

19 *See* Exhibit A.

nominal orbital lifetime of five years. The propulsion system also will provide Swarm with the ability to de-orbit its satellites more rapidly upon command.

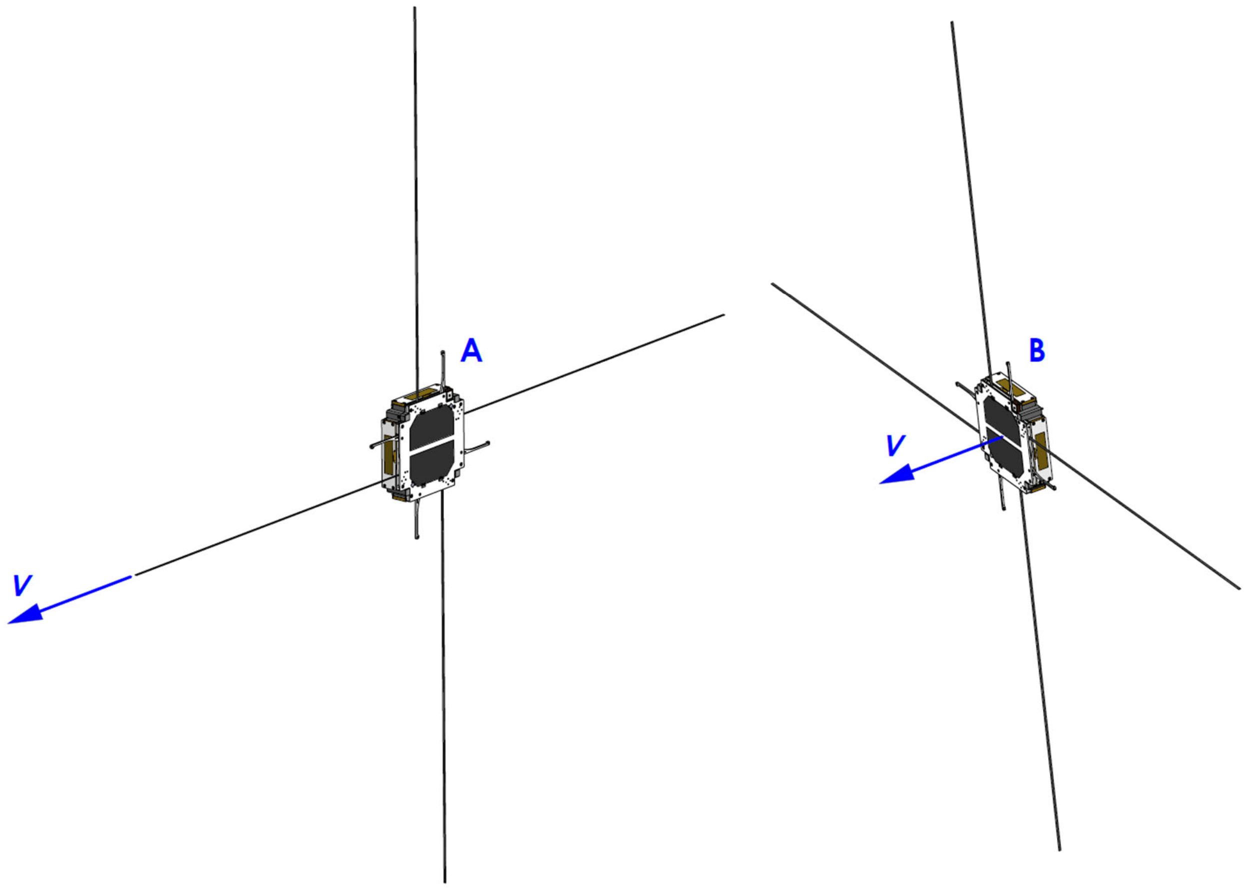

Figure 2. Flight configurations for a Swarm satellite, where "v" represents the velocity vector. (A) A Swarm satellite in the low-drag flight configuration. (B) A Swarm satellite in high-drag flight configuration to de-orbit more rapidly.

III. PUBLIC INTEREST BENEFITS

Under the Commission's rules, "applications for modifications of space station authorizations will be granted" unless an enumerated exception applies.[20] The exceptions relevant here apply to modifications that either seek "to increase the authorized bandwidth" assigned during a processing round, or "would not serve the public interest, convenience, and necessity."[21] When evaluating whether a modification serves the public interest, the Commission has recognized "the length of time it takes to construct a satellite system, the rapid pace of technological change, and the goal of promoting more efficient use of the radio spectrum."[22] The Commission thus has concluded that modifications should be granted where they do not "present any significant interference problem" and are "otherwise consistent with the Commission's policies."[23]

Swarm does not seek an increase in bandwidth in this application, and it was not licensed during a processing round in any event. Moreover, grant of this request in no way presents a "significant interference problem" and only advances Commission policy. As explained above, Swarm is already licensed to transmit from an altitude of 300 km, and PFD levels on the Earth's surface are even lower when a Swarm satellite transmits from 585 km as opposed to 550 km.

In addition, the modifications sought in this application will provide Swarm with the flexibility it needs to deploy services as rapidly as possible while also enhancing Swarm's contribution to a safe space environment. The Commission already has expressed interest in mandating propulsion at these altitudes,[24] and Swarm stands ready to meet that objective. With the

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20 *See* 47 C.F.R. § 25.117(d)(2).

21 *Id.* § 25.117(d)(2)(ii).

22 *Applications of The Boeing Company*, Order and Authorization, 18 FCC Rcd. 12,317 ¶ 7 (Int'l Bur. 2003).

23 *Teledesic LLC*, Order and Authorization, 14 FCC Rcd. 2261 ¶ 5 (Int'l Bur. 1999).

24 *See Orbital Debris Update Order* ¶ 164.

flexibility to implement propulsion well ahead of the Commission's schedule, Swarm can improve the existing ability of its satellites to reach and maintain their position in orbit, maneuver around colliding objects, and de-orbit rapidly at the end of their missions. Replacing Ku-band reflectors in favor of GPS antennas likewise will improve the trackability of Swarm's constellation. Under the NASA DAS analysis, the marginal increase in the lifetime of a Swarm satellite deployed at 585 km as opposed to 550 km will have a negligible impact on collision risk, which can be mitigated by Swarm's maneuvering capabilities in any event. Accordingly, the Commission should grant this application.

IV. 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.

/s/ Kyle Wesson
Kyle Wesson, Ph.D.
Regulatory Engineer
Swarm Technologies, Inc.