ATTACHMENT A - TECHNICAL DESCRIPTION
Myriota NVNG VHF Satellite System

This Attachment provides the Federal Communications Commission ("Commission") with the information required by 47 C.F.R. §25.114 and other relevant sections of Part 25 of the Commission's rules.

A.1 GENERAL DESCRIPTION

Myriota intends to operate a non-voice, non-geostationary ("NVNG") satellite system employing small satellites with advanced signal processing techniques and low-power Internet of Things ("IoT") modules with non-directional antennas to provide connectivity for a new generation of IoT devices in the United States and around the world (the "Myriota System"). In this Petition, Myriota seeks Commission authority to operate the Myriota System in the 137-138 MHz and 148-150.05 MHz bands (the "NVNG VHF Bands").

Myriota previously filed a petition for declaratory ruling requesting authority for the Myriota System to operate in the 399.9-400.05 MHz (Earth-to-space) and 400.15-401 MHz (space-to-Earth) bands (the "NVNG UHF Bands").[1] The NVNG VHF Bands will be included in the payload of satellites in the Myriota System.

With the exception of the additional spectrum use, the satellite system information provided in the *NVNG UHF Petition* remains unchanged by this Petition. Accordingly, in the interest of administrative convenience and brevity, the Technical Description focuses on operations in the NVNG VHF Bands. Other Myriota System information that is unchanged from the *NVNG UHF Petition* is hereby incorporated by reference.

A.1.1 Orbital Parameters

The orbital parameters of the Myriota System were fully described in the *NVNG UHF Petition*, accompanying materials, and additional information submitted in the docket of the proceeding. This Petition will have no material impact on the orbital parameters of the Myriota System, which were included in the *NVNG UHF Petition* and are included in the Schedule S associated with this Petition.

In addition, Myriota acknowledges the need to coordinate the physical operation of Myriota System satellites, which may be deployed at various orbital altitudes, with other NGSO systems and satellites.

[1] *See* File No. SAT-PDR-20190328-00020 (filed March 28, 2019), Call Sign S3047 ("*NVNG UHF Petition*").

A.1.2 Proposed Spectrum

Myriota seeks authority to operate the Myriota System throughout the 137-138 MHz and 148-150.05 MHz bands. These bands are allocated for use by MSS systems and associated earth stations that may operate while in-motion or while stationary.

The 137-138 MHz band is allocated for space service downlinks for Federal and non-Federal uses on a co-primary basis in the space operation service, meteorological satellite service, MSS, and the space research service.[2] Additionally, operations in the downlink band in the MSS are subject to a number of service rules to protect NOAA meteorological satellite systems.[3]

The 148-150.05 MHz band is allocated to MSS (Earth-to-space) on a co-primary basis for Federal and non-Federal use and is also limited to NVNG systems. The 148-149.9 MHz frequency band is allocated by footnote to the space operation service (Earth-to-space) on a co-primary basis with Federal and non-Federal uses.[4] The 148-149.9 MHz frequency band is also allocated to the fixed service ("FS") and mobile service ("MS") on a co-primary basis for Federal use.[5] The 149.9-150.05 MHz band is allocated to the radionavigation-satellite service ("RNSS") on a co-primary basis.[6]

The use of TT&C spectrum by the Myriota System is addressed separately below.

A.2 PREDICTED SPACE STATION ANTENNA GAIN CONTOURS

The predicated space station antenna gain contours of the Myriota System was fully described in the *NVNG UHF Petition* and accompanying materials. This Petition will have no material impact on the predicated space station antenna gain contours of the Myriota System. All satellites in the Myriota NVNG system have been designed with the same transmit and receive antenna characteristics, and are identical for NVNG UHF and NVNG VHF frequency bands.

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[2] 47 C.F.R. § 2.106.

[3] 47 C.F.R. § 25.259.

[4] 47 C.F.R. § 2.106, n. 5.218 (space operation service operations in the 148-149.9 MHz band are subject to agreement obtained under No. 9.21 of the ITU Radio Regulations. The bandwidth of any individual transmission shall not exceed ±25 kHz).

[5] *Id.* at n. 5.219 (MSS operations in the 148-149.9 MHz band must be coordinated under No. 9.11A of the ITU Radio Regulations and use of the band by the MSS shall not constrain the development and use of the fixed, mobile and space operation services in this band).

[6] *Id.* at n. 5.220 (MSS operations in the 149.9-150.05 MHz band must be coordinated under No. 9.11A of the ITU Radio Regulations and use of the band by the MSS shall not constrain the development and use of the band by the radionavigation satellite-service).

The antenna gain contours for the beams of a representative space station, which are essentially the same for satellites operating in all planes within the constellation, are identical to those demonstrated in the *NVNG UHF Petition* and are included in the Schedule S associated with this Petition.

A.3 TT&C CHARACTERISTICS

The TT&C operations of the Myriota System were fully described in the *NVNG UHF Petition* and accompanying materials. This Petition will have no material impact on the TT&C operations of the Myriota System.

Although Myriota will have a point of contact that can respond to issues and inquiries, TT&C operations of the Myriota System will be conducted using TT&C earth station facilities located outside the United States. Therefore, Myriota does not seek Commission authority with respect to TT&C operations at this time.

However, Myriota has contracted with Tyvak Nanosatellite Systems Inc. ("Tyvak") to coordinate operations of the Myriota NVNG system from Tyvak's satellite network command center in Irvine, California. Thus, in addition to Myriota's point of contact, the Commission will have access to Myriota's subcontracted network control facility in the United States to addressed relevant issues as they arise.

A.4 CESSATION OF EMISSIONS

Each active satellite transmission chain (channel amplifiers and associated solid state power amplifier) can be individually turned on and off by ground telecommand, thereby complying with the cessation of emissions requirement of Section 25.207 of the Commission's rules.[7]

A.5 SPECTRUM COMPATIBILITY

The NVNG VHF Bands have been designated by the Commission for use by commercial NVNG systems. These bands are also shared with other services as indicated in the U.S. Table of Frequency Allocations.

As required by Section 25.142 of the Commission's rules (except as waived, in part, as requested in this Petition), Myriota below (i) demonstrates the operational characteristics of the Myriota System that will allow it to operate in a manner that will not cause harmful or unacceptable interference to any NVNG system;[8] (ii) provides the power flux-density ("PFD") produced by its system at the Earth's surface in the 137-138 MHz band to demonstrate that no coordination with terrestrial systems is necessary; (iii) describes how it would protect the radioastronomy service in the 150.05-153 MHz band from harmful interference from unwanted emissions; (iv) demonstrates compliance with applicable emission limitations; and (v) commits to coordination with Federal government users.[9]

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[7] 47 C.F.R. § 25.207.

[8] *See* 47 C.F.R. § 25.142(a)(1)-(3); *see also* Petition, Section IV.A (Waiver Request).

[9] *See* 47 C.F.R. § 25.142(a)(1)-(3).

Myriota has designed its NVNG system to achieve a high degree of flexibility and spectral efficiency in order to facilitate frequency sharing and to avoid causing harmful interference to other authorized systems and services in compliance with U.S. and international regulations. For example, as illustrated by Figure A.5-1, below, the Myriota System's satellites can vary channel bandwidth with onboard processing across the entire range of both the uplink and downlink frequency bands authorized for its use.

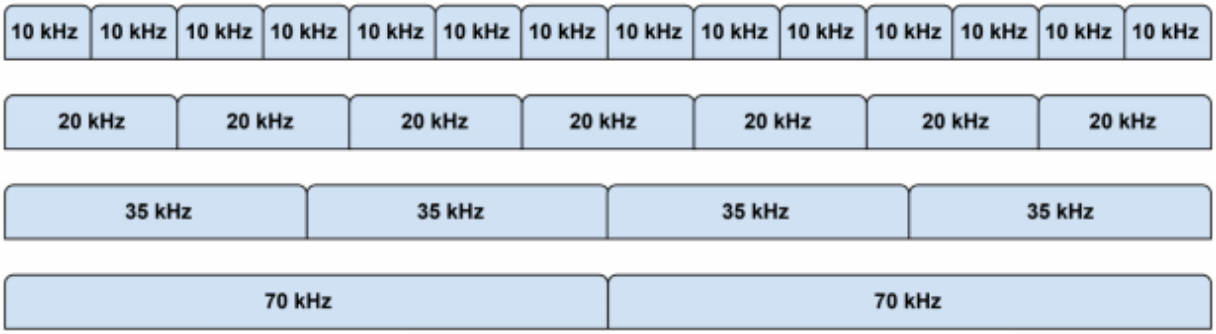

Figure A.5-1. Example Illustration of Channel Variations

Consistent with applicable rules and under good faith coordination arrangements, Myriota can utilize its ability to dynamically select channels for use depending on the availability of spectrum for use by a particular satellite (*e.g.*, the presence of another NVNG satellite operating co-frequency that itself would not be required to alter its operations based on the outcome of coordination with Myriota).

In addition, Myriota's operating parameters are flexible. For example, the Myriota System can vary its power levels and duty cycles to facilitate co-frequency operation of multiple NVNG systems.

By applying these and other sharing approaches, Myriota and other NVNG systems can successfully share the NVNG VHF Bands.

A.5.1 Spectrum Sharing with Other NVNG Satellite Systems

Two NVNG MSS systems are authorized to operate in the NVNG VHF Bands: ORBCOMM License Corp. a subsidiary of ORBCOMM, Inc. (collectively, "ORBCOMM"), and Swarm Technologies, Inc. ("Swarm"). ORBCOMM is authorized to operate in specific sub-bands in the 137-138 MHz and 148-150.05 MHz bands on an exclusive and shared basis.[10] Additionally, ORBCOMM is conditionally authorized to operate throughout the 137-138 MHz and 148-150.05 MHz frequency bands until commencement of operations by another U.S.-licensed NVNG system.[11] Swarm Technologies, Inc. is licensed to operate in specific sub-bands,

[10] *See* ORBCOMM License Corp., Application For Authority to Modify its Non-Voice, Non-Geostationary Satellite System, Order and Authorization, DA Dkt. No. 08-633, ¶¶ 22-23 (rel. Mar. 2, 2008) ("*2008 ORBCOMM Order*"); *see also* ORBCOMM License Corp., File No. SAT-MOD-20111021-00207 and associated amendments (partial grants of Apr. 25, 2013 and Dec. 17, 2015).

[11] *2008 ORBCOMM Order*, ¶ 10, 11 (also assigning "System 1" frequencies to ORBCOMM).

without overlapping ORBCOMM's exclusive authorized bands.[12]

Myriota has completed an analysis of ORBCOMM's satellite operations and believes there is opportunity for Myriota to operate on a non-harmful interference basis vis-à-vis ORBCOMM. In the uplink (Earth-to-space) direction of transmission, there is opportunity for Myriota's IoT modules to transmit low-power signals on occasions when ORBCOMM satellites are not within radio line-of-sight or are at low elevation angles (where the path loss is increased). This will significantly limit the potential for harmful interference caused to ORBCOMM's satellite receivers.

Furthermore, transmissions from ORBCOMM earth stations are expected to be at substantially higher power than those of Myriota (possibly by 10 dB), which enables ORBCOMM's satellites to receive the higher-power signals despite Myriota's lower-power operations.

In the downlink (space-to-Earth) direction of transmission, opportunity exists for Myriota satellites to transmit when there is no overlap of satellite footprint with ORBCOMM satellites. ORBCOMM has 35 space objects in orbit and even assuming an extreme scenario in which all 35 satellites are operating, ORBCOMM does not provide continuous coverage throughout the United States. The satellite footprint can be determined for an applicable elevation angle and overlapping downlink transmission can be avoided (*e.g.*, downlink performed at specific times and locations can minimize the potential for harmful interference).

In addition, it appears that Myriota and Swarm would be able to accommodate co-frequency operation of their respective NVNG systems through coordination and defining suitable duty cycle and power limits.

A.5.1.1 137-138 MHz

Both ORBCOMM and Swarm are authorized by the Commission to operate in various segments of the 137-138 MHz band for downlink operations. Myriota has the flexibility and spectral efficiency to be able to operate harmoniously with ORBCOMM and Swarm in this band. As stated above, Myriota's satellites are able to vary the bandwidth of their emissions through on-board processing, and dynamically control their emissions to accommodate sharing arrangements with other users of the band.

Myriota downlink emissions can range in bandwidth between 10-100 kHz and operate within the entire 1 MHz MSS allocation or any portion thereof designated for their use. Myriota downlink emissions can employ frequency hopping to move throughout the assigned band,

[12] Swarm Technologies, Inc., Application for Authority to Deploy and Operate a Non-Voice, Non-Geostationary Lower Earth Orbit Satellite System in the Mobile-Satellite Services, *Memorandum Opinion and Order*, ¶ 8 (rel. Oct. 17, 2019) ("*Swarm Order*"). Swarm is authorized to operate in the 137.0250-137.1750 MHz, 137.3275-137.3750 MHz, 137.4725-137.5350 MHz, 137.5850-137.6500 MHz, and 137.8125-138.0000 MHz (space-to-Earth) bands; and the 148.2500-148.5850 MHz, 148.6350148.7500 MHz, and 149.9000-149.9500 MHz (Earth-to-space) bands. *Swarm Order*, ¶ 18(a). Swarm's operations in the 137.825-138.000 MHz band are on a secondary basis only. *Id.*, ¶ 18(b).

or operate with a defined channel plan, using either multiple contiguous channels or a fragmented channel arrangement.

In addition, the Myriota System has a system-wide duty cycle (*i.e.*, percentage of time for transmit and receive operations between Myriota satellites and IoT devices and micro-gateways) of no more than 10%. By combining the low duty cycle with the flexibility of the software-defined radio onboard its satellites, Myriota will be able to share spectrum by coordinating geographic use and/or time of operations.

To the extent that information sharing can help facilitate spectrum access (*e.g.*, to facilitate NVNG operations in a particular frequency range in a particular geographic region), it would be possible to use the presently NVNG VHF Bands more efficiently. However, Myriota believes that accommodating other NVNG systems in the NVNG VHF Bands will require a new NVNG processing round rather than demonstrations of non-interference pursuant to undefined standards vis-à-vis NVNG systems with ambiguous regulatory status.

A.5.1.2 148-150.05 MHz

Both Myriota and Swarm operate in various segments of the 148-150.05 MHz band for uplink operations. Myriota's system would be able to share this band with other NVNG systems without causing harmful interference.

Both IoT modules and micro-gateways transmit only when a Myriota satellite is overhead, significantly reducing the times during which interference is even theoretically possible.

Myriota's IoT modules can operate with less than 5 dBW EIRP. Myriota's IoT modules will operate with typical transmit duty cycle less than 0.02%, and occasionally with duty cycle of 0.5%. They employ frequency hopping across the intended band, with a narrow emission bandwidth of just 2 kHz.

Myriota's micro-gateways will typically operate with transmit duty cycle less than 0.5% and occasionally up to 5%, with emission bandwidth ranging from 10-100 kHz. Since the micro-gateways are far less numerous than other devices communicating with Myriota satellites in this band, their slightly higher duty cycle will have a negligible effect on the spectrum environment.

These operating characteristics give Myriota the ability to share the spectrum available in the 2.05 MHz range with other NVNG systems also operating in the 148-150.05 MHz band.

Myriota also affirms that it will, at the direction of the Commission, cooperate fully and make every reasonable effort to resolve technical problems and conflicts that may inhibit effective and efficient use of the radio spectrum. Even absent Commission direction, Myriota will seek to coordinate its proposed frequency usage with both ORBCOMM and Swarm as needed.

A.5.2 Spectrum Sharing with Respect to Terrestrial Networks

Section 25.142(a)(2) of the Commission's rules requires applicants for NVNG MSS authorizations to provide the PFD produced at the Earth's surface by each space station in the 137-138 MHz band, to allow determination of whether coordination with terrestrial services is required under any applicable footnote of the U.S. table of frequency allocations. For 137-138 MHz, the PFD threshold is -125 dB(W/m^2 4kHz) at the Earth's surface.[13] Myriota's satellite emissions will be controlled to ensure this PFD limit is not exceeded.

To demonstrate compliance with this limit, Myriota has included Table A.5.2-1 calculating the PFD for a satellite in Myriota's system, assuming operations at maximum power, at both initial and lowest altitudes where it will perform commercial operations. Myriota's maximum PFD operations are identical to, and fully described in the *NVNG UHF Petition* and accompanying materials.

Satellite altitude (km)	600	400
Antenna Gain (dBi)	2.15	2.15
Maximum EIRP (dBW) (for arbitrary bandwidth 80 kHz)	14.5	11
Maximum EIRP density (dBW/4 kHz)	1.5	-2
Spreading loss (dB)	-126.555	-123.033
PFD (dBW/m^2/4 kHz)	-125.055	-125.033

Table A.5.2-1 Maximum PFD at the Surface of the Earth

In addition, Myriota's satellites comply with the requirement set forth 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 discussed above. Signals received from terrestrial sources are demodulated and processed onboard the satellite. An appropriate response is then generated, modulated, and transmitted by the satellite. Unknown or incompatible signals received by a satellite are rejected and do not result in a transmission response, ensuring that signals originating from sources outside of the Myriota network will not be re-transmitted.

A.5.3 Protection of Radio Astronomy in the Adjacent 150.05-153 MHz Band

Section 25.142(a)(2) of the Commission's rules also directs applicants for NVNG authorizations to discuss the measures they would employ to protect the Radio Astronomy Service ("RAS") in the 150.05-153 MHz band from harmful interference from unwanted emissions.[14] Myriota appreciates the importance of protecting RAS sites worldwide against harmful interference.

[13] *See* ITU Radio Regulations, Appendix 5, Annex 1, ¶ 1.1.1 (Coordination thresholds for sharing between MSS (space-to-Earth) and terrestrial services in the same frequency bands).

[14] *See* 47 C.F.R. § 25.142(a)(2).

In the 137-138 MHz downlink band, the theoretical worst-case Doppler shift will be ±3.53 kHz. These effects are insignificant relative to the frequency separation between the NVNG and RAS operations (12,050 kHz separation between boundaries at 138 MHz and 150.05 MHz). As a result, Doppler effects will not frequency shift the signal into the RAS band.

RAS facilities are generally vulnerable to interference from satellite transmissions due to the high-gain antennas used on many satellites, which tend to concentrate energy in a specific direction and can unintentionally point towards an RAS antenna. By contrast, Myriota's satellite transmit power spectral densities will be extremely low in the 150.05-153 MHz range. Over any 4 kHz measured bandwidth in this range, the EIRP spectral density from a Myriota satellite emission will be attenuated at least 55 dB through front-end filtering compared to the emission at frequency of operation. This equates to a PFD value at the Earth's surface of less than -180 dBW/m^2/4 kHz. Moreover, Myriota's downlink emissions will not be continuous over time, with duty cycle 10% or less. This reduces the average power received at the RAS site and further reduces the probability of harmful interference.

Uplink transmissions from Myriota's IoT modules and micro-gateways will occur in the 148-150.05 MHz band. RAS facilities have considerably lower antenna gain in the direction of potential terrestrial interferers (*i.e.*, they benefit from significant antenna discrimination at very low elevation angles). It is very unlikely that Myriota's IoT modules will cause harmful interference into RAS facilities because the IoT modules can operate with EIRP less than 5 dBW in the 148-150.05 MHz band, and emissions outside this band will be reduced by at least 40 dB over any 4 kHz measured bandwidth through front-end filtering. Myriota's IoT modules will operate with a low duty cycle (typically less than 0.02%), which further reduces the average power received by a RAS facility. In addition, Myriota will manage the deployment of its micro-gateways such that they avoid interference potential to RAS facilities.

If a specific RAS site nonetheless experiences interference, Myriota can utilize its geofencing technology to prevent IoT modules from ever transmitting within certain distances of a given location. Myriota has employed this strategy to protect the Square Kilometer Array in Australia and could apply it to other RAS sites as appropriate. Myriota can even send messages instructing specific NVNG terrestrial stations to cease transmission should interference concerns arise.

A.5.4 Compliance with Emission Limits

Section 25.142(a)(3)(i) requires applicants for NVNG authorizations to show that their space stations will not exceed the emission limitations specified in Sections 25.202(f)(1)-(3), as calculated for a fixed point on the Earth's surface in the plane of the space station's orbit, considering the worst-case frequency tolerance of all frequency determining components, and maximum positive and negative Doppler shift of both the uplink and downlink signals, taking into account system design. Myriota's satellite hardware is designed to conform with the emission limits of Section 25.202(f), for a range of possible emission bandwidths 10-100 kHz.

For a satellite launched to an altitude of 600 km, the worst-case Doppler shift is 3.479 kHz, occurring at the upper limit of the 137-138 MHz downlink band. As shown in Table A.5.4-1 below, as these satellites gradually lose altitude over time, the Doppler shift increases

slightly. To be conservative, assuming worst case Doppler shift of 3.53 kHz would comfortably accommodate any such difference in satellite altitude.

Satellite altitude	Transmit frequency	Doppler shift
600 km	137 MHz	3.454 kHz
	138 MHz	3.479 kHz
400 km	137 MHz	3.504 kHz
	138 MHz	3.530 kHz

Table A.5.4-1 Doppler Shift at Various Altitudes

Myriota's satellite hardware is designed to conform with the emission limits of Section 25.202(f), for a range of possible emission bandwidths. Figure A.6.4-2 below shows the required emission mask necessary to conform to these emission limits, assuming an example emission bandwidth of 80 kHz, for both worst-case Doppler effects (shown in red) and without considering Doppler effects (shown in blue). Myriota's satellites will conform to these limits.

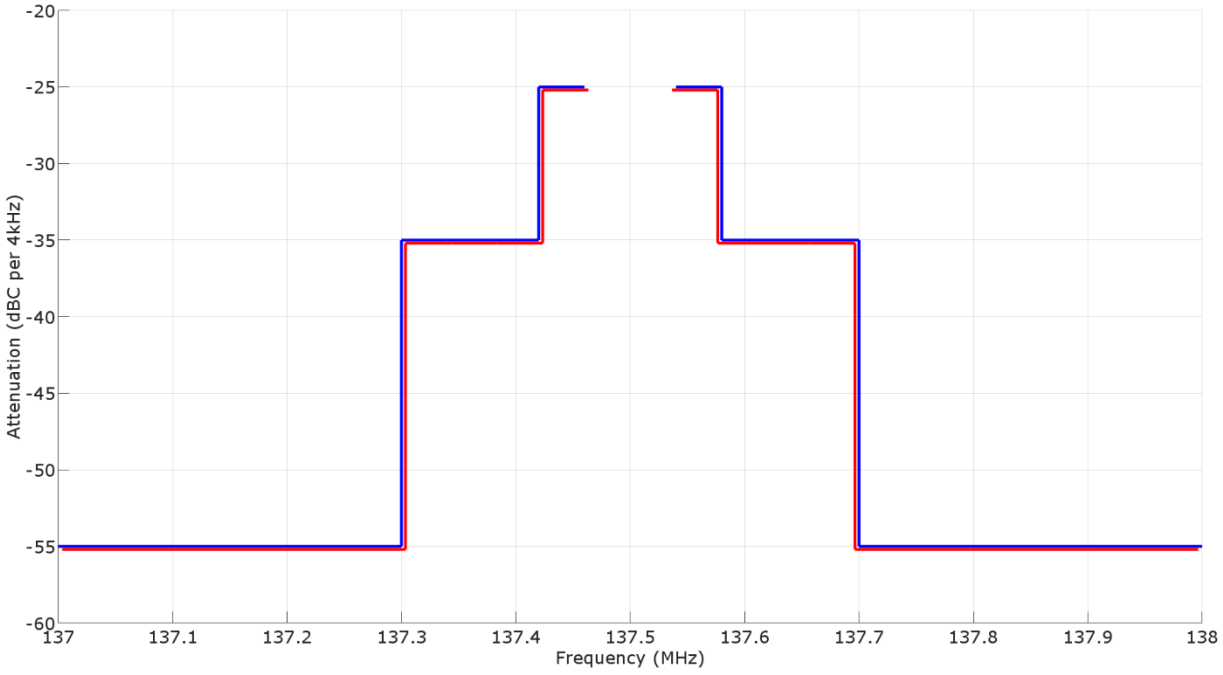

Figure A.5.4.-2 Spectral Emission Limits

A.5.5 Spectrum Sharing with Respect to GSO Satellite Systems

Section 25.289 of the Commission's rules provides that an NGSO system licensee must not cause unacceptable interference to, or claim protection from, a GSO FSS or GSO BSS

network.[15] However, there are no GSO satellite systems currently licensed by the Commission or granted U.S. market access in the bands at issue in this petition. Accordingly, there is no basis for concern with respect to potential interference to GSO satellite systems.

A.5.6 Coordination with U.S. Government Networks

There are a variety of Federal allocations in the spectrum Myriota proposes to use for its NVNG operations in the U.S., including Space Research, Meteorological-Satellite and Space Operation in the 137-138 MHz band, and Fixed Services, Mobile, and Radionavigation-Satellite in the 148-150.05 MHz band.[16] Section 25.142(b)(2) of the Commission's rules notes these allocations, and the Commission's role as liaison with the National Telecommunications and Information Administration ("NTIA") to reach agreement with respect to achieving compatible operations between federal government users and commercial NVNG systems.

Myriota's agile and spectrally efficient system will facilitate coordination with Federal spectrum users and ensure that no harmful or unacceptable interference will be caused to such users. Myriota acknowledges and accepts that any grant of U.S. market access authority will be conditioned on coordinating with the Commission and NTIA to adequately protect Federal government operations, and Myriota will provide additional information as requested by the Commission.

Myriota is also prepared to operate consistent with the requirements of Section 25.259 to protect National Oceanic and Atmospheric Administration ("NOAA") operations in the 137-138 MHz band.[17] Myriota is capable of complying with the regulations regarding restriction of transmissions into the "protection area" of NOAA satellites described in Section 25.259(a). In addition, as required under Section 25.259(b), Myriota will provide a 24/7 point of contact so that any reports of potential interference can be resolved expeditiously.

In addition, each Myriota satellite will automatically cease satellite transmissions if, after 72 consecutive hours, no reset signal is received from Myriota network control and verified by the satellite. All satellites in the Myriota System will be capable of instantaneous shutdown on any sub-band upon command.

A.6 NO VOICE SERVICES PROVIDED

Myriota affirms that it will not be providing voice services, in compliance with Section 25.142(b)(1).

[15] *See* 47 C.F.R. § 25.289.

[16] *See* 47 C.F.R. § 2.106.

[17] *See* 47 C.F.R. § 25.259.

A.7 ITU FILINGS FOR MYRIOTA

The Myriota NVNG system will operate under network filings made on its behalf with the ITU by the Australian administration under the satellite network name MNSAT. A request for coordination of this filing was published in BR IFIC 2878 on September 4, 2018.

A.8 ORBITAL DEBRIS MITIGATION

The orbital debris mitigation and satellite end-of-life plan of the Myriota System was described in the *NVNG UHF Petition*, accompanying materials, and additional information submitted in the docket of the proceeding. This Petition will have no material impact on the orbital debris mitigation and satellite end-of-life issues of the Myriota System.

Myriota reaffirms that it will continue to take into account orbital debris mitigation and satellite end-of-life issues in its operational plans, particular given potential differences in orbit altitude of its satellites. As orbital debris mitigation and satellite end-of-life planning is necessarily forward looking may benefit improvements to the processes and procedures submitted to the Commission, Myriota will continue to engage with the Space Situational Awareness community and update the Commission regarding any refinements to is orbital debris mitigation and satellite end-of-life plans, as appropriate.

In addition, Myriota acknowledges the need to coordinate the physical operation of Myriota System satellites, which may be deployed at various orbital altitudes, with other NGSO systems and satellites.

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this Petition for Declaratory Ruling, 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

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