Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Momentus Space LLC	)	File No. SAT-LOA_____
	)	
Authority to Deploy and Operate the Vigoride-5 as a Non-Geostationary Orbit In-Space Transportation Spacecraft	)	

APPLICATION

Tony Lin
Emma Marion
DLA Piper LLP (US)
500 8th Street, NW
Washington, DC 20004
+1 (202) 779-4450
Counsel for Momentus Space LLC

Paul Ney
Chief Legal Officer
Momentus Space LLC
3901 N. First Street
San Jose, CA 95134
+1 (650) 564-7820

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APPLICATION

I. Introduction

By this application, Momentus Space LLC ("Momentus"), a wholly owned subsidiary of Momentus Inc. f/k/a Stable Road Acquisition Corporation, requests authority, pursuant to 47 C.F.R. § 25.113(g), to deploy and operate the Vigoride-5 ("VR-5") non-geostationary orbit ("NGSO") spacecraft in low-Earth orbit ("LEO"), to transport and deploy multiple, separate customer payloads, and to conduct certain hosted-payload, experimental operations on behalf of The California Institute of Technology's High-Speed Integrated Circuits Group ("Caltech").

VR-5 will operate in the S-band (2025-2110 MHz) for Space Operations (Earth-to-space), in the X-band (8025-8400 MHz) for Space Operations (space-to-Earth), and at 9984 MHz for the hosted-payload, experimental operations. VR-5 is scheduled to be deployed from a Space Exploration Technologies Corporation ("SpaceX") Falcon 9 launch in October 2022, and the mission is expected to have a duration of 250 days.

Momentus previously filed an application for VR-5[1] under the Part 25 Special Temporary Authority ("STA") rules, consistent with past practice of the International Bureau ("Bureau").[2] Pursuant to discussions with Bureau staff, Momentus is now refiling the VR-5 mission pursuant to the Commission's conventional Part 25 satellite authorization rules.[3] The application is materially the same as that previously filed.[4]

Momentus is a U.S. commercial space company headquartered in San Jose, California, that trades on the NASDAQ Global Select market under the ticker symbol: MNTS.[5] Since its founding in 2017, Momentus has brought together a team of engineering, technology and business experts united by the mission of providing the backbone infrastructure services to help people, industries, and companies use space in new ways. There are three infrastructure services

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[1] Application of Momentus Space LLC, IBFS File No. SAT-STA-20220310-00028 (filed Mar. 11, 2022).

[2] *See, e.g.,* Application of Spaceflight, IBFS File No. SAT-STA-20210205-00017 (granted May 28, 2021); Application of Spaceflight, IBFS File No. SAT-SAT-20180523-00042 (granted Oct. 12, 2018); Application of Spaceflight, IBFS File No. SAT-SAT-20150821-00060 (granted Oct. 26, 2016); Application of Momentus Space LLC, IBFS File No. SAT-STA-20211216-00195 (granted April 28, 2022). As the Commission has recognized, there are currently no standards specifically adopted for in-space transportation operations. *See Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 4156 at 4191-4195 ¶¶77-81 (2020).

[3] 47 C.F.R. § 25.113(g).

[4] More specifically, the refiled application reflects: an updated ground station list and corresponding antenna gain contours; an updated customer payload manifest; updated ownership information; updated launch parameters; modest changes to the concept of operations ("CONOPS") – specifically, an additional operational orbit and an approximately 2-month increase in mission duration; additional information regarding compliance with PFD limits in the X-band frequencies and orbital debris mitigation information, consistent with the filings made to the FCC with respect to the Momentus VR-3 mission, IBFS File No. SAT-STA-20211216-00195; updated and corrected technical information; added text to clarify certain Schedule S parameters; and revised waiver requests resulting from the change in procedural process (e.g., waiver of modified processing round rules and the milestone and bond requirements). Momentus has also updated the Schedule S and ODAR to reflect the changes identified above, as well as to clarify text and/or correct parameters. Additionally, Momentus has reorganized the presentation of the information for clarity and made other ministerial changes.

[5] Ownership information for Momentus is provided in Exhibit 4 attached.

that Momentus anticipates will be commonplace demands of the future: 1) in-space transportation to carry customer satellites to precise custom orbits; 2) hosted payloads to provide customers with continual power, orbit keeping, orientation and communication services (also known as "Satellite as a Service"); and 3) in-orbit services like refueling, repositioning, repairing, and de-orbiting satellites. The company believes it can make these new ways of operating in space possible with its planned in-space transfer and service vehicles that will be powered by the company's innovative water plasma-based propulsion system that is under development. When these future services are available, space-faring customers can reap the benefits of investing more time in their payloads and technologies and rely on service-providers, like Momentus, to navigate the in-space logistics needed for mission success. With respect to the hosted payload, Caltech's experimental operations will further scientific and engineering knowledge, which in turn will further innovation and strengthen the U.S. economy. For these reasons, Momentus submits that the public interest would be served by grant of the application.

II. System Description

A. General System Description

The Vigoride spacecraft product line is comprised of self-propulsive, free-flying spacecraft designed to transport and deploy customer payloads, permanently host customer payloads and, in future iterations, perform on-orbit services including rendezvous, proximity operations and debris removal. Propelled primarily by a novel microwave electrothermal thruster ("MET"), which is designed to be non-toxic and low-pressurized water propellant system capable of providing orbit transfers, Vigorides are designed to be capable of the transportation and deployment of dozens of individual payloads which may be scheduled for deployment at any point after orbital insertion and prior to deorbit.

Figure 1: Artist's rendering of Vigoride deploying a customer spacecraft

With respect to this application, VR-5 will transport a total of five (5) third-party payloads. Four of the five payloads are Momentus customer cubesats that will be deployed directly from VR-5. The other payload, SSPD-1, will not deploy, but will remain as a hosted payload on VR-5.[6]

Exhibit 5 provides a summary of the third-party payloads and related information, including effective drag area and maximum deployed dimensions. Each of the payload owners (except for the hosted payload owner) is contractually obligated to obtain and certify that it has obtained all necessary authorizations for operation of its payload prior to integration with VR-5 and the launch vehicle and provide evidence of such authorizations to Momentus.

The VR-5 mission operations center is located at the company headquarters in San Jose, California. All primary telemetry and commanding will be handled through this facility, via

[6] SSPD-1 includes the MAPLE payload discussed below.

commercial ground stations, using encrypted links. Additional information on the ground segment is provided in section II.B.5 below.

VR-5 has a planned launch on a Falcon 9 rideshare in October 2022. VR-5 will be affixed directly to the Falcon 9 vehicle and deployed into a targeted sun-synchronous orbit with approximately a ~97.5 degree inclination and an insertion orbit between 500 to 550 km circular orbit.[7] After separation from the launch vehicle, VR-5 will undergo commissioning and, upon completion, will deploy all but one of the deployable payloads. *See* Exhibit 5.

After those initial payload deployments, VR-5 will conduct orbital maneuvers to reach a 538 km circular sun-synchronous orbit with a ~97.5 degree inclination. VR-5 will then deploy the last payload and subsequently commence hosted payload operations. Subsequently, VR-5 will maneuver to a 541 km circular sun-synchronous orbit and then commence hosted payload operations.

Afterwards, VR-5 will conduct further orbit maneuvers and inclination adjustments to a targeted 541 km x 350 km elliptical orbit with a ~98 degree inclination. *See* Table 1 below (summarizing the relevant orbital parameters for the mission).

As demonstrated in the attached ODAR (*see* Exhibit 2), a 550 km circular sun-synchronous orbit would be the worst-case scenario in the assessment of orbital debris risk, and VR-5 would re-enter the Earth's atmosphere in approximately 12 years at that altitude. At the targeted final orbit, 541 km x 350 km, Momentus calculates that VR-5 will de-orbit within approximately 1 year.

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[7] For the purposes of this application, Momentus assumed a 550 km maximum insertion orbit based on information from the launch provider.

B. Technical Specifications

1. Orbital Parameters

The VR-5 concept of operations is as follows:

1. Launch vehicle arrives at initial orbit (maximum 550 km altitude circular sun-synchronous orbit ("SSO")).
2. VR-5 separates from launch vehicle.
3. VR-5 undergoes commissioning and preliminary testing.
4. VR-5 deploys all but one deployable payload.
5. If the insertion orbit is higher than 538 km, then VR-5 conducts orbit reduction maneuvers to second orbit (538 km circular SSO). If insertion orbit is lower than 538 km, then VR-5 conducts orbit raise maneuvers to second orbit (538 km circular SSO).
6. VR-5 deploys Qosmosys ZEUS-1.
7. VR-5 conducts orbit raising maneuvers to 541 km circular SSO.
8. VR-5 commences operations of hosted payload.
9. VR-5 conducts orbit and inclination adjustment maneuvers to the final end-of-life orbit (maximum 541 km x 350 km elliptical with a ~98° inclination). As discussed in the ODAR, Momentus will take actions, as it passes through the orbit of any inhabitable spacecraft, to mitigate risk to such spacecraft.

	VR-5 Insertion Orbit	**Second Orbit**	**Third Orbit**	**VR-5 Final Orbit**
Apogee Altitude	550 km (max)	538 km	541 km	541 km
Perigee Altitude	550 km (max)	538 km	541 km	350 km
Inclination	~97.5° +/- 0.1° (SSO)	~97.5° (SSO)	~97.5° (SSO)	~98° (Elliptical)
Period	96 mins	95 mins	95 mins	94 mins
Argument of Perigee	N/A	N/A	N/A	N/A
Local Time of the Ascending Node (LTAN)	~09:30 + 60 min	~09:30	~09:30	N/A

Maximum De-Orbit Life	VR-5[8] ~12 years	VR-5[9] ~ 8 years	VR-5[10] ~ 8 years	VR-5 ~ 1 year

Table 1: Orbital Parameters

2. Frequency Bands

VR-5 will operate in the S-band (2025-2110 MHz) for Space Operations (Earth-to-space), in the X-band (8025-8400 MHz) for Space Operations (space-to-Earth), and in the 9984 MHz Band for experimental purposes. The use of the S-band and X-band frequencies will be primarily for telemetry, tracking, and command ("TT&C"). *See* Table 2 below. However, Momentus will also downlink imagery generated from one or more on-board cameras to confirm successful deployment of the payloads and perform mission assurance functions.[11] Information regarding the use of the 9984 MHz Band is provided in Exhibit 6.

Criteria	Uplink (Earth-to-space)	Downlink (space-to-Earth)	Notes
Center Frequency	2075.0 MHz[12]	8200 MHz	
Bandwidth (max.)	0.1 MHz	1 MHz	
Data Rate	50 kbps	500 kbps	Data rate is configurable from

[8] This is the deorbit duration, if VR-5 fails after deployment.

[9] This is the deorbit duration, if VR-5 achieves the second orbit and then the propulsion system fails.

[10] This is the deorbit duration, if VR-5 achieves the third orbit and then the propulsion system fails.

[11] Momentus holds a commercial remote sensing license issued by the National Oceanic and Atmospheric Administration ("NOAA") for the operations of imaging sensors. *See* NOAA Licensees, https://www.nesdis.noaa.gov/commercial-space/regulatory-affairs/licensing/noaa-licensees (last visited Dec. 10, 2021).

[12] Both the identified center frequencies are representative frequency channels. As a result of coordination with federal operators, Momentus may select another channel within the identified frequency bands for its operations.

			approximately 1 kbps up to a maximum listed
Modulation & Coding	BPSK	OQPSK	Links may include FEC.
Transmit Power	9W	1.5W	
Transmit Antenna	4.5m (dish)	Patch (6 dBiC)	
Transmit Antenna EIRP	43 dBW	2.3 dBW	
Receive Antenna	Patch (7 dBiC)	Dish (48 dBiC)	
Receive Antenna G/T	-26 dB/K	25 dB/K	

Table 2: Radio Frequency Plan

a. S-band and X-band Frequencies

The S-band (2025-2110 MHz) and X-band (8025-8400 MHz) frequency bands each have allocations internationally and in the U.S. for EESS use. Specifically, the 2025-2110 MHz (Earth-to-space) band is allocated for non-Federal EESS and Space Operations use, subject to conditions as may be applied on a case-by-case basis and the limitation that any use may not cause harmful interference to authorized Federal and non-Federal operations.[13] As discussed below, Momentus requests waiver of the Table of Allocations to the extent necessary.[14] Momentus is aware that there are federal and other operations in these frequency bands and intends to coordinate its proposed operations with affected operators prior to operations.

[13] *See* 47 C.F.R. § 2.106 n.US347. The 2025-2110 MHz (Earth-to-space) band is also allocated to space operations internationally. 47 C.F.R. § 2.106.

[14] *See infra* Section III.A.

Provided as Exhibit 7 is an interference analysis demonstrating that the X-band operations will not cause harmful interference to authorized spectrum operations.

Attached to this application, please find antenna gain contours for transmit and receive antenna beams showing, in 2 dB steps, to 10 dB below max gain.[15] The peak gain value for the transmit beam is 6 dB. The peak gain value for the receive beam is 7 dB.

VR-5 will also include a demonstration X-band radio and patch antennas, built by Momentus, called CHIRP. The CHIRP demonstration has the same RF characteristics as the primary X-band radio and antenna. CHIRP will only transmit while VR-5 is over Momentus' identified ground stations and when the primary X-band radio is not transmitting.

b. X-band Interference Analysis

VR-5 meets the International Telecommunication Union ("ITU")-established power flux density ("PFD") limits on the Earth's surface and at the geostationary arc and adequately limits emissions in the adjacent band frequencies.

i. X-band PFD at the Earth's Surface

The Commission's rules do not contain limits on PFD at the Earth's surface produced by emissions from space stations operating in the 8025–8400 MHz band.[16] However, Table 21-4 of the ITU Radio Regulations ("ITU RR") specifies that the PFD at the Earth's surface produced by emissions from a space station in the 8025–8400 MHz band, including emissions from a reflecting satellite, must not exceed the following values:

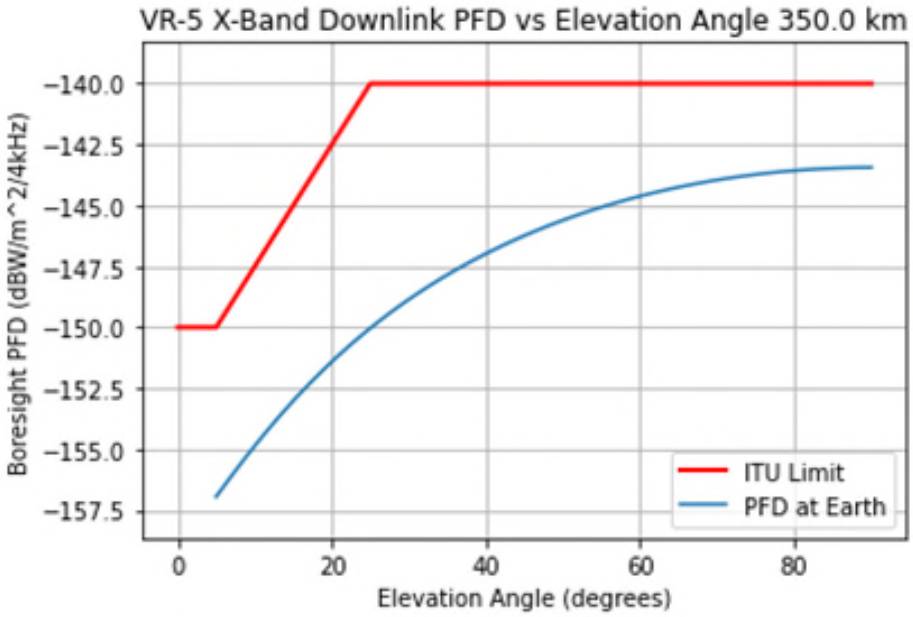
- -150 dB(W/m²) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;

[15] *See* Exhibit 3.

[16] 47 C.F.R. § 25.208.

- -150 + 0.5(δ – 5) dB(W/m²) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -140 dB(W/m²) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

As shown in the figure below, the PFDs at the Earth's surface produced by VR-5 satisfy the PFD limits for all angles of arrival calculated at the 350 km orbital altitude, which is the lowest nominal operating orbital altitude for VR-5. To the extent possible and helpful for de-orbiting, Momentus will continue to conduct TT&C communications during the period when the perigee of VR-5 is below 350 km and until as low as 150 km, as VR-5 is de-orbiting. In that event, Momentus will reduce the power levels of its transmissions to maintain compliance with the PFD limit in all likelihood with a margin of at least 3 dB.



ii. PFD at the Geostationary-Satellite Orbit

ITU RR 22.5 states that in 8025-8400 MHz band "the maximum power flux-density produced at the geostationary-satellite orbit by any Earth exploration-satellite service space station shall not exceed −174 dB(W/m^2) in any 4 kHz band." At the maximum 550 km altitude

for VR-5, assuming the spacecraft is pointed directly at geostationary orbit, the PFD would be approximately -190 dBW/m^2, which complies with the limit.

PFD Calculation
==========
P = 1.5 W
P = -34.26 dBW per 4.0 kHz Ref BW
θ = 0 °
D = 35286.0 km
Gt = 3.98
PFD = -190.2 dBW/m^2 @ 4.0 kHz Ref BW

iii. Protection of authorized X-band satellite operators

The Momentus VR-5 mission plans to use a 1-megahertz channel (8199.5-8200.5 MHz) in the X-band Earth-Exploration Satellite Service allocation (space-to-Earth) on an unprotected and non-interference basis for Space Operations services. The attached report included as Exhibit 7 demonstrates that the VR-5 spacecraft operations will not cause unacceptable levels of interference to authorized satellite systems in these X-band frequencies and, further, by maintaining a 3-degree avoidance angle with other co-frequency satellite operators will ensure protection of those systems.

iv. Out-of-band emissions in the 8400-8450 MHz band

ITU-R Recommendation SA-1157-1 specifies a maximum allowable interference power spectral flux density level ("PSFD") at the Earth's surface to protect ground receivers in the deep-space research band operating in the 8400–8450 MHz frequencies.[17] Momentus complies with this requirement by using a combination of baseband digital filtering and hardware radio frequency filtering, which is projected to provide 70 dB of filtering. Moreover, Momentus'

[17] *See* Recommendation ITU-R SA.1157-1 (Protection criteria for deep-space research) (2006).

highest band edge is approximately 200 megahertz below the lowest band edge for the 8400–8450 MHz band, which would result in further attenuation.

Momentus calculates a maximum PSFD at the Earth's surface of -263 dB(W/m^2 / Hz), which is below the maximum allowable interference power spectral flux-density level at the Earth's surface of -255.1 dB(W/m^2*Hz) at 8.4 GHz.[18] The maximum interference PSFD was calculated as follows:

VR-5 maximum PFD (at 350 km altitude)[19] = -143 dB(W/m^2*4 kHz)
Total Attenuation at 8.4 GHz relative to 8.2 GHz (filtering and guard band) = at least 80 dB

PSFD = PFD - 10*log(4000) – Attenuation
PSFD = -143 dB(W/m^2*4000 Hz) - 10*log(4000) dB - 80 dB
PSFD = -259 dB(W/m^2*Hz)

3. Schedule S Clarifications

Momentus notes that the minimum and maximum Saturation Flux Density ("SFD") values in the Schedule S are generally relevant only to GSO, bent-pipe communication links. Nonetheless, Momentus calculates minimum and maximum SFD values for this NGSO spacecraft with regenerative links and provides in the Schedule S the range of PFD values expected at the satellites over the full range of operational orbital altitudes, gateway Earth station EIRP levels and elevation angles.

[18] *Id.*

[19] To the extent possible and helpful for de-orbiting, Momentus will continue to conduct TT&C communications during the period when the perigee of VR-5 is below 350 km and until as low as 150 km, as VR-5 is de-orbiting. In that event, Momentus will reduce the power levels of its transmissions to maintain compliance with the limit, in most cases with a margin of at least 3 dB.

4. Frequency Tolerance and Emission Limitations

Momentus will comply with the frequency tolerance requirements of 47 C.F.R. § 25.202(e) and the emission limitations of 47 C.F.R. § 25.202(f). In addition, VR-5's transmitter does not turn on automatically, and manual commands from the ground are required to initiate communications from the spacecraft. Accordingly, VR-5 complies with 47 C.F.R. § 25.207.

5. Ground Stations

For the VR-5 mission, Momentus intends to utilize RBC Signals, LLC ("RBC") as the ground segment provider. RBC currently operates a ground station network that aggregates capacity of existing satellite ground stations around the world.[20] All operational communications between the Momentus Mission Operation Center ("MOC") and RBC stations will be protected by levels of encryption appropriate to secure control over the VR-5. To that end, TT&C transmissions will be sent using packetized protocols incorporating end-to-end AES256 encryption.[21] Table 3 below identifies the ground stations from which RBC will communicate with the VR-5.[22]

Location	**Latitude °**	**Longitude °**
Deadhorse, Alaska	70°12'36" N	148°00'00" W
Jeju Island, South Korea	35°32'24" N	126°00'00" E

[20] While RBC operates a network of approximately fifty ground stations, for the VR-5 mission, only those stations identified in Table 3 will be used.

[21] RBC will not receive any keys necessary to decrypt or otherwise manipulate any packetized TT&C instructions sent from the MOC to VR-5.

[22] Momentus expects that it will have, as a minimum, between four to five passes per day over each of the identified ground stations (*i.e.*, four to five opportunities per day per station to communicate with VR-5) but may nominally have in excess of nineteen such passes in any given day. Each communication window presents an average of approximately seven minutes contact time.

Stockholm, Sweden	59°39'00" N	16°34'48" E
Dublin, Ireland	53°24'36" N	6°13'12" W
Cape Town, South Africa	34°1'48" S	18°34'12" E

Table 3: RBC Ground Stations Supporting VR-5

6. Microwave Electrothermal Thruster

VR-5 uses a radiofrequency generator that emits electromagnetic energy at a maximum theoretical power level of 750 watts to operate the thruster. This generator uses a magnetron to efficiently produce this level of power output, which, in turn, is delivered via a bolted waveguide connection to the thruster chamber. The location of the generator and the application of shielding mitigates the radiation of emissions outside of the thruster. The emission frequency generated by the magnetron is fixed and operates at 5750 MHz +/- 250 MHz. Electromagnetic Interference emission levels from the flight thruster payload have been measured in an anechoic facility, indicating emissions of less than 10 uV/m at a distance of 300 meters. In addition, there is expected to be further attenuation given the aluminum structure surrounding the thruster, which has no gaps larger than the wavelength (~5 cm).

Momentus' proposed thruster operations will not cause harmful radiofrequency interference to incumbent services. The narrow frequency range around 5750 MHz is used on a primary basis by Radiolocation and Fixed-Satellite (Earth-to-space) and is used on a secondary basis by the Amateur and Amateur-Satellite radio services in all three ITU regions.[23] The power flux density at the Earth's surface from 150 km, the estimated closest operational distance to the

[23] *See* 47 C.F.R. § 2.106.

satellite, is far below the PFD threshold specified in the ITU Radio Regulations.[24] At the calculated emission levels, no emissions will be detectable (by a very large margin) by radar, mobile, fixed, or amateur systems. All other emissions from the thruster (*e.g.*, harmonics and sub-harmonics) will be further attenuated by at least an additional 20 dB.[25]

More specifically, per our calculations, the PFD at the Earth's surface is approximately -221 dB(W/m^2), which meets the limits specified in ITU RR 21.16 for all angles of arrival.

PFD Calculation
==========
PFD = P*G/(4*π*D^2)
P = -7.27 dBW/4kHz Ref BW (750W)
θ = 0°
D = 150.0 km (worst case - decommissioning)
G = 1E-10 (as measured)[26]
PFD = -221.78 dBW/m^2 @ 4.0 kHz Ref BW

C. Hosted Payload

Momentus will host an experimental light-weight flexible phased array system – called MAPLE – on board the VR-5 satellite. MAPLE and the associated experiments are designed by Caltech and run by Caltech in cooperation with Momentus. Technical and other information about MAPLE is provided in Exhibit 6.

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[24] *See* ITU Radio Regulations 21.16.

[25] Due to the operation of the equipment as part of the spacecraft, Momentus believes the VR-5 thruster should not be characterized as Industrial, Scientific or Medical equipment. *See* 47 C.F.R. §18.101, *et. seq*. In any event, as discussed above, due to the low calculated emissions levels, the frequency range within which the thruster will operate, and the operations of the equipment in space, the emissions from the propulsion system are unlikely to cause harmful interference to any authorized services.

[26] As measured, there is a gain of less than -100 dBi within the 5670-5725 MHz range.

D. Orbital Debris Mitigation

Momentus has conducted an ODAR in compliance with NASA-STD-8719.14, which is attached as a separate exhibit (Exhibit 2). As discussed in the submitted ODAR, the VR-5 is compliant with all applicable orbital debris requirements.

VR-5 is planned to operate with an approximately 20% margin of propellant, in addition to the propellant necessary to achieve the operational concept. Momentus calculates that this reserve will be sufficient to support all contingencies during the VR-5 mission, including orbital debris and object avoidance maneuvers throughout the mission life. Additionally, Momentus calculates that it would have sufficient propellant remaining at the conclusion of the mission to conduct further perigee reduction maneuvers which could reduce to months the demise of the VR-5.

If there are any changes to the customer manifest, Momentus may replace a customer payload with a mass dummy, which would not be deployed on orbit, as discussed in the attached ODAR. Any such mass dummies to replace Momentus customer payloads would simulate the mechanical interfaces and mass of the customer spacecraft and allow Momentus to conduct a demonstration of the planned deployment without any deployment in fact occurring. The ability to replace any payload with a mass dummy, as necessary, is key to the ongoing certification of the VR-5 mass properties to the launch service provider and ensuring orbital debris compliance for the mission.

III. Waiver Requests

The Commission may waive any of its rules if there is "good cause" to do so.[27] In general, waiver is appropriate if (1) special circumstances warrant a deviation from the general rule; and (2) such deviation would better serve the public interest than would strict adherence to the rule.[28] Generally, the Commission will grant a waiver of its rules in a particular case if the relief requested would not undermine the policy objective of the rule in question and would otherwise serve the public interest.[29] Here, the development of efficient, flexible and non-toxic space transportation infrastructure, and the benefits such a service provide – including, critically, the potential to assist in orbital debris risk mitigation – represent a special circumstance warranting waiver of the FCC rules. With respect to the MAPLE experimental operations, a waiver is warranted because the experiments, which are run by Caltech, are intended to further scientific and engineering knowledge and allowing this sort of experimentation furthers innovation and strengthens the U.S. economy.

A. U.S. Table of Frequency Allocations

1. 2025-2110 MHz TT&C Uplink

This band is allocated to Space Operations and Earth-Exploration Satellites Services ("EESS"), *inter alia*, in all ITU regions. In the United States, Space Operations are limited to federal operators, and EESS use by commercial operators is subject to conditions as may be applied on a case-by-case basis and the limitation that any use may not cause harmful

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[27] *See* 47 C.F.R. § 1.3; *Northeast Cellular Tel. Co. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).

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

[29] *See WAIT Radio*, 418 F.2d at 1157.

interference to authorized operations.[30] Accordingly, to the extent necessary, Momentus requests waiver of the Table of Allocations to use the 2025-2110 MHz band (Earth-to-space) for TT&C. Given the limited use of the frequencies during the brief 250-day mission, Momentus' commitment to coordinate use of these frequencies, and the public interest justification supporting the mission, Momentus submits that waiver is warranted.

1. 8025-8400 MHz TT&C Downlink

This band is allocated to EESS (space-to-Earth), *inter alia*, in all ITU regions and in the United States. For VR-5, the 8025-8400 MHz band is, as discussed above, to be used primarily for TT&C and some satellite imaging.[31] Accordingly, to the extent necessary, Momentus requests waiver of the U.S. Table of Frequency Allocations.

Momentus intends to engage in the following activities that will mitigate the potential for harmful interference:

- limit operations to approximately 250 days;
- transmit only over identified ground stations, many of which are located in regions not typically used for earth-exploration satellite service systems;
- limit use to a one-megahertz bandwidth channel using OQPSK modulation;
- operate on an unprotected and non-harmful interference basis; and
- pre-coordinate operations with potentially affected federal operators.

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[30] *See* 47 C.F.R. § 2.106 n. US347.

[31] Such use will also include transmission of limited imagery of the payloads during deployment primarily to provide mission assurance and, to a limited degree, selected images for publicity or marketing purposes.

Given the limited use of the frequencies during the brief 250-day mission, Momentus' commitment to coordinate use of these frequencies, the demonstrated showing of non-harmful interference, and the public interest justification supporting the mission, Momentus submits that waiver is warranted.

2. 9984 MHz

The 9900-10000 MHz band, which includes 9984 MHz, is allocated in the U.S. for radiolocation, and internationally for meteorological-satellite services, and accordingly, the proposed satellite transmission is not consistent with the U.S. Table of Frequency Allocations, 47 C.F.R. §2.106.

Momentus requests waiver of the U.S. Table of Frequency Allocations to allow the use of the frequency 9984 MHz with an occupied bandwidth of 10 MHz for transmission of a signal at most four times per day (and more likely once per day) to an earth station located at Pasadena, California on the Caltech campus. This frequency was chosen because it is ideally suited to look at the functioning of an experimental phased array system and the possibility of focusing that phased array to allow for power transfer over radio waves. This use of this frequency would be temporary. Should the technology work as expected, then Caltech would likely conduct additional experiments on other frequency bands to determine which frequencies are best suited to this purpose.

Waiver of the U.S. Table of Frequency Allocations is justified for the following reasons:

- The experiment is not likely to cause harmful interference to authorized users. First, the experiment is limited in scope and duration. Transmission will be limited to a maximum of four 15-minute passes per day (and more likely only one 15-minute transmission will take place on any given day) and the total duration of the testing is expected to last no

longer than 250 days. Second, the transmission will operate at very low power (0.6 W) and, accordingly, is not likely to cause harmful interference to authorized operators.

- There is flexibility in the timing of the MAPLE transmission and the transmissions can be coordinated to further mitigate potential interference as necessary.
- Experimentation is in the public interest. Caltech, which is conducting and supporting the experiment, is experimenting to further scientific and engineering knowledge. Allowing this sort of experimentation furthers innovation and strengthens the U.S. economy.
- The experiment would be conducted on an unprotected and non-harmful interference basis. If Momentus or Caltech becomes aware of any harmful interference, the parties will discontinue operations.

B. Modified Processing Round Rules

Momentus requests that this application be processed pursuant to the first-come, first-served procedure adopted for "GSO-like satellite systems" under Section 25.158 of the Commission's rules.[32] To the extent necessary to allow for such processing, Momentus also requests waiver of Sections 25.156 and 25.157 of the Commission's rules, which stipulate the processing of "NGSO-like satellite systems" under a modified processing round framework.[33]

The Commission has not required modified processing rounds and essentially allowed similar in-orbit servicing missions to be processed on a first-come, first-served basis on multiple

[32] 47 C.F.R. § 25.158.

[33] 47 C.F.R. §§ 25.156 and 25.157.

occasions.[34] The Commission explained in *Swarm* that "[t]he purpose of the processing round procedure is to prevent one applicant from unreasonably precluding additional entry by other operators in the requested frequency band."[35] Similarly in the *Space Imaging, LLC Order*, the Commission waived its processing round requirements, concluding that authorizing Space Imaging to operate in its requested EESS frequency bands would not preclude other NGSO operators from operating in those bands because EESS NGSO operators are generally capable of sharing spectrum in the same frequency.[36] Subsequent waivers have been granted to other EESS operators, each premised on a showing that such operators would be capable of sharing with current and future NGSO systems operating in the same frequency bands.[37]

Momentus' spectrum use would be limited in time and location, and Momentus is capable of both sharing the spectrum on which it proposes to operate and operating on a non-interference basis. A grant of Momentus' requested authorization would not preclude later grants of applications for the same spectrum. Accordingly, the underlying basis of the processing round rules would not be served by applying them under these circumstances here.

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[34] Application of Spaceflight, IBFS File No. SAT-STA-20210205-00017 (granted May 28, 2021); Application of Spaceflight, IBFS File No. SAT-SAT-20180523-00042 (granted Oct. 12, 2018); Application of Spaceflight, IBFS File No. SAT-SAT-20150821-00060 (granted Oct. 26, 2016); Application of Momentus Space LLC, IBFS File No. SAT-STA-20211216-00195 (granted April 28, 2022).

[35] *See Swarm Technologies, Inc.*, Memorandum Opinion, Order and Authorization, 34 FCC Rcd 9469, ¶ 16 (2019).

[36] *See Space Imaging, LLC*, Declaratory Order and Order and Authorization, 20 FCC Rcd 11694, 11968 (2005).

[37] *See, e.g.*, Spire Global, Inc. SAT-LOA-20151123-00078 (granted Oct. 14, 2016); Planet Labs, Inc., SAT-LOA20130626-00087 (granted Dec. 3, 2013); Skybox Imaging, Inc., SAT-LOA-20120322- 00058 (granted Sep. 20, 2012).

C. Milestone and Bond Requirements

Momentus requests waiver of the Commission's milestone and bond requirements for NGSO systems.[38] The Commission's bond requirements have been developed to prevent licenses from warehousing spectrum.[39] Momentus does not seek mutually exclusive use of the spectrum used, as discussed above. A grant of Momentus' requested authorization would not preclude other operators from seeking authorization to use the frequency bands proposed by Momentus. Accordingly, there is no basis to impose the milestone or bond requirements.

Additionally, as the Commission has recognized, the anticipated time period for implementation and overall length of time that individual satellites are expected to operate are relevant considerations with regards to public interest benefits of bond requirements.[40] Here, the mission life for VR-5, a single spacecraft, is expected to be less than one year.

Another consideration that underlies the Commission's bond requirements is the Commission's concern not to impose a cost that is disproportionate to the overall cost of the mission.[41] The Commission has stated: "we note that the cost of maintaining a $3 million or $5

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[38] *See* 47 C.F.R. §§ 25.164, 25.165.

[39] *See Comprehensive Review of Licensing and Operating Rules for Satellite Services*, Second Report and Order, 30 FCC Rcd 14713, ¶ 53 (2015) (citing, *e.g.*, *TMI Communications and Company, Limited Partnership and TerreStar Networks Inc.*, *Application for Review and Request for Stay*, Memorandum Opinion and Order, 19 FCC Rcd 12603, 12604, ¶ 2 (2004); *PanAmSat Licensee Corp.*, A*pplication for Authority to Construct, Launch, and Operate a Ka-Band Communications Satellite System in the Fixed-Satellite Service at Orbital Locations 58° W.L. and 125° W.L.*, Memorandum Opinion and Order, 16 FCC Rcd 11534, 11537-38, ¶ 12 (2001)).

[40] *In the Matter of Streamlining Licensing Procedures for Small Satellites*, Notice of Proposed Rulemaking, 33 FCC Rcd 4152, ¶ 51 (2019). The ultimate rule adopted by the Commission for small satellites provides that individual satellites must have a lifetime from deployment of six years or less. 47 C.F.R. § 25.123(b)(2).

[41] *See In the Matter of Amendment of the Commission's Space Station Licensing Rules and Policies*, First Order on Reconsideration and Fifth Report and Order, 19 FCC Rcd 12637, ¶¶ 28-31 (2004).

million final bond during satellite construction is nominal in comparison with the cost to implement licensed space stations, which generally cost several hundred million dollars each to launch and operate."[42] For NGSO constellations with costs to construct and launch measured in the billions, a $5 million bond and associated fees might indeed be viewed as "nominal." But for a single satellite with an extremely limited mission duration, the bond and associated fee, even for a short period of time, would be excessive and would be a disproportionate and unfair cost. For these reasons, Momentus submits that waiver of the milestone and bond requirements is justified.

D. Annual Regulatory Fee

For the same reasons stated above, Momentus also requests that the FCC waive in advance any application of the FCC's annual satellite fee for NGSO systems to VR-5. Given the brief duration of the mission, the potential assessment of a $122,695 annual fee would be excessive, disproportionate, and unfair.

IV. ITU Compliance

Momentus has prepared the ITU Advance Publication Information submission for its proposed system and is contemporaneously providing this information to the FCC under separate cover. Attached as an exhibit to this application is a signed ITU cost-recovery declaration.

Respectfully submitted,

/s/ Paul Ney

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[42] *In the Matter of Comprehensive Review of Licensing and Operating Rules for Satellite Services*, Second Report and Order, 30 FCC Rcd 14713, ¶ 60 (2016).

Tony Lin
Emma Marion
DLA Piper LLP (US)
500 8th Street, NW
Washington, DC 20004
+1 (202) 779-4450
Counsel for Momentus Space LLC

Paul Ney
Chief Legal Officer
Momentus Space LLC
3091 N. First Street
San Jose, CA 95134
+1 (650) 564-7820

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