Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Momentus Inc.	)	File No. SAT-STA_____
	)	
Application for Special Temporary Authority	)	
to Launch and Operate an In-Space	)	
Transportation Spacecraft	)	
	)	

APPLICATION FOR SPECIAL TEMPORARY AUTHORITY

Tony Lin
George John
Hogan Lovells US LLP
555 13th Street, NW
Washington, DC 20004
+1-202-637-5795

Philip Hover-Smoot
Regulatory Affairs
Momentus Inc.
3050 Kenneth Street
Santa Clara, CA 95054
+1-650-564-7820

Counsel for Momentus Inc.

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APPLICATION FOR SPECIAL TEMPORARY AUTHORITY

I. Introduction

By this application, Momentus Inc. ("Momentus") requests Special Temporary Authority, pursuant to 47 C.F.R. § 25.120, to launch and operate the Vigoride-1 ("VR-1") non-geostationary orbit spacecraft in low-Earth orbit and to transport and deploy multiple, separate customer payloads to specified final orbital destinations. VR-1 will operate in the S-band (2025-2110 MHz) for Space Operations (Earth-to-space) and in the Ultra High Frequency ("UHF") band (400.15-401 MHz) for Space Operations (space-to-Earth). VR-1 is expected to be deployed from a Falcon 9 launch in May 2020, and the mission is expected to have a duration of 180 days, *i.e.*, from May 2020 to November 2020.

Momentus is a private U.S. company headquartered in Santa Clara, California. Momentus is engaged in the design, construction, and operation of in-space transportation spacecraft. Since its inception, Momentus has built a team of aerospace professionals, drawn from throughout the industry, united with the singular goal of changing how the world thinks about space transport. Through its revolutionary Vigoride spacecraft, which are capable of transporting and delivering small satellites to exact orbital locations, Momentus will provide efficient and inexpensive "connecting flights" in space. The ability to customize orbits using

Vigoride spacecraft empowers small satellite operators by enabling greater and safer use of all orbits, including high-density orbits. For all of 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 is a self-propulsive, free-flying spacecraft designed to transport and deploy customer payloads. For the initial mission, VR-1 will have the capacity to transport and deploy multiple payloads (individually, "Payload 1," "Payload 2," and "Payload 3," and together, the "Payloads"). Payload 1 is expected to be a standard 6U cubesat and Payloads 2 and 3 are expected to be standard 3U cubesats.

The spacecraft is propelled primarily by a microwave electrothermal thruster ("MET"), which uses non-toxic and low-pressurized water propellant to provide low-thrust orbit transfers.[1] Momentus' innovative technology and propulsion system recently won a NASA iTech award.[2]

The VR-1 mission operations center is located at the company headquarters in Santa Clara, California. All primary telemetry and commanding will be handled through this facility using encrypted links.

VR-1 has a planned launch on a SpaceX Falcon 9 rocket in May 2020. VR-1 will be affixed directly to the payload of the Falcon 9 and deployed into a 220 by 380 km elliptical orbit with a 53 degree inclination[3]. After separation from the launch vehicle, VR-1 will undergo

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[1] VR-1 will also have onboard four experimental reaction control thrusters that also use the same propellant.

[2] *See NASA iTech Winners Impress with Tech Ideas for use in Space, on Earth*, NASA, https://go.nasa.gov/365KB8N (last edited Jul. 16, 2019).

[3] The launch vehicle operator has indicated it may select an alternative insertion orbit of 289 km circular. In that event, Momentus will notify the FCC by letter. For completeness, the Orbital Debris Assessment Report submitted with this application includes a decay analysis for that alternative insertion orbit.

commissioning and, upon completion, will conduct orbit-raising maneuvers to a targeted 380 km circular orbit with a 53 degree inclination. At this orbital destination, VR-1 will deploy Payloads 1 and 2.

After deployment of Payloads 1 and 2, VR-1 will conduct orbit-raising maneuvers to a targeted 500 km circular orbit with a 53 degree inclination. At this orbital destination, VR-1 will deploy Payload 3. *See* Table 1 below (summarizing the relevant orbital parameters for the Payloads and VR-1).

As part of the orbit raising, Momentus will calculate and monitor propellant consumption and reserve a sufficient amount of propellant to ensure that VR-1 will be capable of conducting a final de-orbit maneuver, as discussed below. While Momentus believes that theoretically VR-1 will be able to attain a circular orbit of 500 km, as an operational matter, it is possible that VR-1 will not reach that orbital altitude. Regardless, as demonstrated in the attached Orbital Debris Assessment Report, a 500 km circular orbit would be the worst-case scenario for orbital debris purposes, and Payload 3 and VR-1 would each re-enter the Earth's atmosphere in less than 4 years at that altitude.

Following deployment of Payload 3, VR-1 will engage in de-orbit maneuvers to lower the perigee of the spacecraft to 300 km altitude. At a (maximum) 500 x 300 km orbit, Momentus calculates that VR-1 will de-orbit within one year. Naturally, if VR-1 does not reach a 500 km circular orbit, the VR-1 de-orbit period will be even shorter after completion of the de-orbit maneuver.[4]

[4] For example, if VR-1 reaches only a 475 km circular orbit, then upon completion of the de-orbit maneuver VR-1 will be in a 475 x 300 km orbit, which is expected to have a de-orbit duration of less than one year.

Momentus intends for the Payloads to be customer satellites. Each customer will be required to obtain all necessary authorizations for operation of its spacecraft prior to integration with VR-1 and the launch vehicle, and Momentus will require proof of such authorization as part of its contractual arrangements with its customers. In order to meet the VR-1 launch schedule, Momentus may launch mass dummies instead of customer spacecraft. The mass dummies would simulate the mechanical interfaces and mass of potential future customer assets and allow Momentus to conduct a technology demonstration. Momentus will inform the Federal Communications Commission ("FCC") of the specific Payloads and relevant licensing administrations, if applicable, sixty (60) days prior to integration with the launch vehicle.

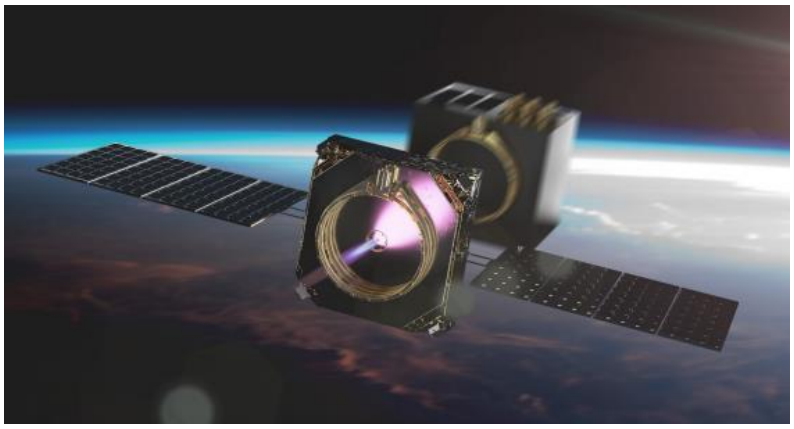

Figure 1: Artist's rendering of Vigoride deploying a customer spacecraft

B. Technical Specifications

1. Orbital Parameters

The VR-1 concept of operations is as follows:

1. Launch vehicle arrives at initial orbit (220x380 km nominal)[5]
2. VR-1 separates from launch vehicle
3. VR-1 undergoes commissioning and testing

[5] *See supra* note 3 (discussing the potential alternative insertion orbit of 289 km circular).

4. VR-1 conducts orbit raising maneuvers to second orbit (max. 380 km circular)
5. VR-1 deploys Payloads 1 and 2
6. VR-1 conducts orbit raising maneuvers to third orbit (max. 500 km circular)
7. VR-1 deploys Payload 3
8. VR-1 conducts de-orbit maneuvers (max. 500 x 300 km)

	Insertion Orbit[6]	Payloads 1 and 2 Orbit	Payload 3 Orbit	VR-1 End-of-Life Orbit
Apogee Altitude	380 km	380 km (max)	500 km (max)	500 km (max)
Perigee Altitude	220 km	380 km (max)	500 km (max)	300 km
Inclination	~53°	~53°	~53°	~53°
Period	90 mins	90-96 mins	90-96 mins	90-96 mins
Argument of Perigee	N/A	N/A	N/A	N/A
Right Ascension of the Ascending Node (RAAN)	Initial Launch RAAN (Falcon 9)	All	All	All
Maximum De-Orbit Life	VR-1[7] 3 months	VR-1[8] 1 year Payloads 1,2 (dummy masses)[9] 15 months	VR-1[10] 3 years Payload 3 (dummy mass) 4 years	VR-1 1 year

Table 1: Orbital Parameters

2. Frequency Bands

VR-1 will operate in the S-band (2025-2110 MHz) for Space Operations (Earth-to-space) and in the UHF band (400.15-401 MHz) for Space Operations (space-to-Earth). *See* Table 2 below. The use of those frequencies will be primarily for telemetry, tracking, and command

[6] *See supra* note 3 (discussing the potential alternative insertion orbit of 289 km circular).
[7] This is the de-orbit duration if VR-1 fails after deployment from the launch vehicle.
[8] This is the de-orbit duration if VR-1 fails after deployment of Payload 1.
[9] In the event that any of the Payloads are customer satellites, the de-orbit analysis will be addressed through the licensing process for the relevant payload.
[10] This is the de-orbit duration if VR-1 reaches a 500 km circular orbit and then fails. At this altitude, VR-1 experiences the worst-case de-orbit duration possible for the mission.

("TT&C"). However, Momentus will also downlink imagery generated from an on-board camera to confirm successful deployment of the Payloads.[11] 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.

Criteria	Uplink (Earth-to-space)	Downlink (space-to-Earth)	Notes
Center Frequency	2075.0 MHz[12]	400.5 MHz	
Bandwidth	0.1 MHz	0.04 MHz	The wider uplink bandwidth accommodates forward error correction ("FEC").
Data Rate	38.4 kbps	38.4 kbps	Data rate is configurable from 1.2 kbps to 38.4 kbps.
Modulation & Coding	2-GFSK (no coding)	2-GFSK (no coding)	Links may include FEC.
Transmit Power	12W	1.8W	
Transmit Antenna	3.0 m (dish)	Dipole (2x monopoles)	
Transmit Antenna EIRP	43 dBW	-9.1 dBW	
Receive Antenna	Patch (7 dBiC)	Yagi (2.5λ)	
Receive Antenna G/T	-32.8 dB/K	-11.6 dB/K	

Table 2: Radio Frequency Plan

[11] Momentus is aware of the requirement to obtain a commercial remote sensing license from the National Oceanic and Atmospheric Administration ("NOAA") for the operations of imaging sensors and intends to comply with all NOAA regulatory requirements. *See* 15 C.F.R. Part 960.

[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.

3. Frequency Tolerance and Emission Limitations

Momentus will fully 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-1's transmitter does not turn on automatically, and manual commands from the ground are required to initiate communications from the spacecraft. Accordingly, VR-1 complies with 47 C.F.R. § 25.207.

4. Ground Stations

For the VR-1 mission, Momentus intends to use Leaf Space S.r.l. ("Leaf Space") as the ground segment provider. Leaf Space currently has four operational ground stations in Europe and plans to operate additional stations in other locations including the United States. Table 3 below identifies the ground stations that Momentus believes will be used to communicate with VR-1.

Location	**Latitude (°N)**	**Longitude (°E)**	**Status**
Milan, Italy	45.59	9.36	Operational
Cork, Ireland	51.95	-8.17	Operational
Puertollano, Spain	38.67	4.16	Operational
Kuanas, Lithuania	54.91	23.99	Operational
Las Cruces, NM, USA	32.27	-106.91	Operational by 04/2020
Southbury, CT, USA	41.45	-73.29	Operational by 04/2020

Table 3: Ground Stations

5. Microwave Electrothermal Thruster

VR-1 uses a radiofrequency generator that emits electromagnetic energy at a maximum power level of 40 watts (16.53 dBW) to operate the thruster. This generator uses a gallium nitride solid-state device to efficiently produce this level of power output, which, in turn, is delivered via a specially shielded coax cable directly to the thruster injector. The emission

frequency generated by the RF Power Module ("RPM") can be adjusted over the frequency range 10.25 to 10.60 GHz. The frequency generator uses a crystal-controlled reference oscillator with a frequency accuracy of 0.28 parts per million, and the synthesizer employed is adjustable over the frequency range, with a resolution of better than 1 kHz. Prior measurements have confirmed that emissions radiating outside of the injector cavity are 100 dB below the maximum generated power output of the RPM. EMI emission levels from the flight thruster payload have been measured in an anechoic facility to ensure that radiated levels do not exceed an RF power level of greater than -50 dBm within the vicinity of the MET (measured at 1 meter from the propulsion system) and that all emissions are contained within a bandwidth of no more than 5 MHz.

Momentus' proposed thruster operations will not cause harmful radiofrequency interfere to incumbent services. The frequency range 10.25 to 10.60 GHz is used on a primary basis by Radiolocation, Fixed, and Mobile services and is used on a secondary basis by the Amateur and Amateur-Satellite radio services in all three International Telecommunication Union ("ITU") regions.[13] The power flux density at the Earth's surface from 220 km, the estimated closest operational distance to the satellite, is far below the PFD threshold specified in the ITU Radio Regulations.[14] 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.

[13] *See* 47 CFR § 2.106.
[14] *See* ITU Radio Regulations 21.16.

III. Waiver Requests

The Commission may waive any of its rules if there is "good cause" to do so.[15] 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.[16] 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.[17] Momentus submits that good cause exists to waive the following rules.

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 interference to authorized operations.[18] As discussed above, Momentus plans to use ground stations in the United States and internationally to communicate with VR-1 for the provision of in-space transportation services. 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 180-day mission, Momentus'

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[15] *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).
[16] *See Northeast Cellular*, 897 F.2d at 1166.
[17] *See WAIT Radio*, 418 F.2d at 1157.
[18] *See* 47 C.F.R. § 2.106 n. US347.

commitment to coordinate use of these frequencies, and the public interest justification supporting the mission, Momentus submits that waiver is warranted.

2. 400.15-401 MHz TT&C Downlink

The 400.15-401 MHz band is allocated for Space Operations (space-to-Earth) on a secondary basis in all ITU regions. As discussed above, Momentus will use these frequencies primarily for TT&C but will also transmit imagery of the Payloads during deployment primarily to ensure mission safety and success. Given the limited use of the frequencies during the brief 180-day mission, Momentus' commitment to coordinate use of these frequencies, and the public interest justification supporting the mission, Momentus submits that waiver is warranted.

Momentus is aware that the FCC established an October 15, 2019 cut-off deadline for requests to operate, *inter alia*, in the 400.15-401 MHz band for the provision of Mobile-Satellite Service.[19] Momentus proposes to use this band for Space Operations on a secondary basis, consistent with the U.S. Table of Frequency Allocations, and its brief and limited use of the band for TT&C is not mutually exclusive with other operations. Accordingly, the request to use these frequencies should be considered outside of the 400.15-401 MHz processing round.

B. 47 C.F.R. § 25.113(g)

The Commission's rules require orbital deployment approval and operating authority to be applied for and granted prior to orbital deployment and operation of a space station. In this case, given (1) the short operational life of the VR-1 spacecraft; (2) the similarity in function of VR-1 to an upper stage launch vehicle; (3) the information contained in this application regarding spacecraft operations and debris mitigation plans; and (4) the public interest justification supporting the mission, Momentus believes the underlying purposes of the rule (to

[19] *See Cut-off Established for Additional NVNG MSS Applications or Petitions for Operations in the 399.9-400.05 MHz and 400.15-401 MHz Bands*, Public Notice, DA 19-779 (rel. Aug. 15, 2019).

provide sufficient information for the FCC to evaluate the satellite mission) is met and that grant of the requested waiver is justified.[20] Further, the FCC has granted similar applications for in-space transportation spacecraft in the recent past.[21]

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 letter.

Respectfully submitted,

/s/ Philip Hover-Smoot

Tony Lin
George John
Hogan Lovells US LLP
555 13th Street, NW
Washington, DC 20004
+1-202-637-5795

Counsel for Momentus Inc.

Philip Hover-Smoot
Regulatory Affairs
Momentus Inc.
3050 Kenneth Street
Santa Clara, CA 95054
+1-650-564-7820

Dated: November 5, 2019

[20] Consistent with FCC precedent, *see infra* note 21, Momentus believes that submission of the Schedule S form is not necessary for processing of this application for special temporary authority. But, the company will submit that information if requested to do so by the FCC.

[21] *See* 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).

EXHIBIT 1

ITU Cost Recovery Letter

DECLARATION

I, Philip Hover-Smoot, hereby declare the following:

Momentus Inc. ("Momentus") is aware that as a result of actions taken at the International Telecommunication Union's 1998 Plenipotentiary Conference, and further modified by the ITU Council in subsequent years, processing fees will now be charged by the ITU for satellite network filings. As a consequence, Commission applicants are responsible for any and all fees charged by the ITU. Momentus hereby states that it is aware of this requirement and unconditionally accepts all cost recovery responsibilities associated with the ITU filings for the Vigoride-1 or VR-1 satellite network. Please address all correspondence related to the Vigoride-1 satellite network to the following point of contact:

Point of Contact Name: Philip Hover-Smoot

Organization Name: Momentus Inc.

Address: 3050 Kenneth Street
Santa Clara, CA 95054

E-Mail: philip.hover-smoot@momentus.space

Telephone Number: +1-650-564-7820

Sincerely,

/s/ Philip Hover-Smoot

Philip Hover-Smoot
Regulatory Affairs
Momentus Inc.

November 5, 2019