

**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**

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Dated: February 21, 2020

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**APPLICATION FOR SPECIAL TEMPORARY AUTHORITY**

**I. Introduction**

By this application, Momentum Inc. (“Momentum”) 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 Soyuz-2 launch in August 2020, and the mission is expected to have a duration of 180 days, *i.e.*, from August 2020 to February 2021.

Momentum is a private U.S. company headquartered in Santa Clara, California. Momentum is engaged in the design, construction, and operation of in-space transportation spacecraft. Since its inception, Momentum 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, Momentum 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” and “Payload 2,” and together, the “Payloads”). Payload 1 is to be a 1.5U cubesat launched on behalf of Steamjet Space Systems. Payload 2 is to be a Spire Inc. 3U Lemur-class cubesat.

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.<sup>1</sup> Momentus’ innovative technology and propulsion system recently won a NASA iTech award.<sup>2</sup>

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 GK Launch Services Soyuz-2 rocket in August 2020. VR-1 will be affixed directly to the payload of the Soyuz-2 and deployed into a 500-565km circular sun-synchronous orbit with approximately a 98 degree inclination<sup>3</sup>. After separation from the launch vehicle, VR-1 will undergo commissioning and, upon completion,

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<sup>1</sup> VR-1 will also have onboard four experimental reaction control thrusters that also use the same propellant.

<sup>2</sup> 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).

<sup>3</sup> In the event of the launch vehicle operator selecting an alternative insertion orbit, Momentus will notify the FCC by letter.

will deploy Payloads 1 and 2. Subsequent to payload deployment, VR-1 will conduct orbit-raising maneuvers to a targeted 585 km circular orbit with a ~98 degree inclination. *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. As demonstrated in the attached Orbital Debris Assessment Report, a 565 km circular orbit would be the worst-case scenario for orbital debris purposes, and VR-1 would re-enter the Earth's atmosphere in less than 23 years at that altitude.

Following demonstration of the orbit adjustment capabilities of the spacecraft, VR-1 will engage in de-orbit maneuvers to lower the perigee of the spacecraft to 450 km altitude. At a (maximum) 585 x 450 km orbit, Momentus calculates that VR-1 will de-orbit within 4 years. Naturally, if VR-1 does not reach a 585 km circular orbit, the VR-1 de-orbit period will be even shorter after completion of the de-orbit maneuver.

All Momentus Payloads will be commercial customer satellites. Currently, Spire Inc. and Steamjet Space Systems are on contract with Momentus for launch on the VR-1 mission. Both customers are contractually obligated to obtain all necessary authorizations for operation of its spacecraft prior to integration with VR-1 and the launch vehicle, and Momentus will confirm each authorization both as part of its contractual arrangements with its customers and its contractual arrangement with the launch service provider. If necessary, and in order to meet the VR-1 launch schedule, Momentus may integrate 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, but would not be deployed in orbit. Momentus will inform the Federal Communications Commission ("FCC") of

any change to the Payloads or the associated relevant licensing administrations, if applicable, at least sixty (60) days prior to integration with the launch vehicle.

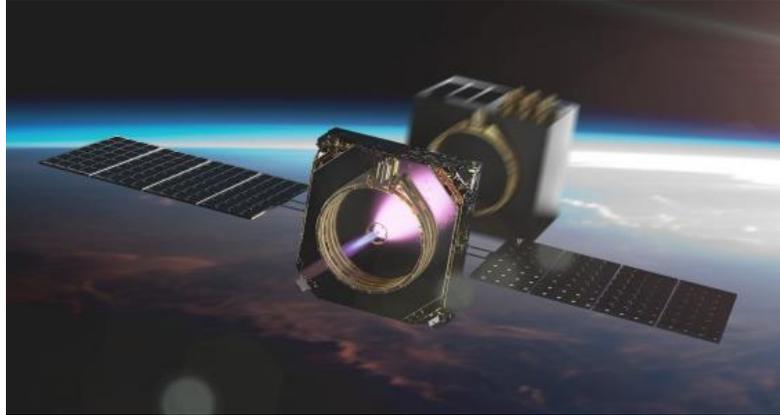


Figure 1: Artist's rendering of Vigoride deploying a customer spacecraft

## **B. Technical Specifications**

### **1. Orbital Parameters**

The VR-1 concept of operations is as follows:

1. Launch vehicle arrives at initial orbit (500-565 km altitude circular)
2. VR-1 separates from launch vehicle
3. VR-1 undergoes commissioning and preliminary testing
4. VR-1 deploys Payloads 1 and 2
5. VR-1 conducts orbit raising maneuvers to second orbit (max. 585 km circular)
6. VR-1 performs detailed system functional testing
7. VR-1 conducts de-orbit maneuvers (targeting 450 km perigee or less)

	<b>Insertion and Payloads 1 and 2 Orbit</b>	<b>VR-1 Transfer Orbit</b>	<b>VR-1 End-of-Life Orbit</b>
<b>Apogee Altitude</b>	565 km (max)	585 km (max)	585 km (max)
<b>Perigee Altitude</b>	565 km (max)	585 km (max)	450 km <sup>4</sup>
<b>Inclination</b>	~97° (Sun-Synchronous)	~97° (Sun-Synchronous)	~97°
<b>Period</b>	96 mins	96 mins	90-96 mins
<b>Argument of Perigee</b>	N/A	N/A	N/A
<b>Local Time of the Ascending Node (LTAN)</b>	~11:00	~11:00	~11:00
<b>Maximum De-Orbit Life</b>	VR-1 <sup>5</sup> 23 years Payload 1 7 years Payload 2 5 years	VR-1 <sup>6</sup> 18 years	VR-1 4 years

**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 (“TT&C”). However, Momentus will also downlink imagery generated from an on-board camera to confirm successful deployment of the Payloads.<sup>7</sup> Momentus is aware that there are

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<sup>4</sup> The minimum possible perigee as a result of de-orbit maneuvers is expected to be 300 km.

<sup>5</sup> This is the de-orbit duration if VR-1 has a propulsion system *and* a solar array deployment failure after deployment from the launch vehicle.

<sup>6</sup> This is the de-orbit duration if VR-1 has a propulsion system failure after raising the orbit to 585 km altitude.

<sup>7</sup> 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.

federal and other operations in these frequency bands and intends to coordinate its proposed operations with affected operators prior to operations.

<b>Criteria</b>	<b>Uplink (Earth-to-space)</b>	<b>Downlink (space-to-Earth)</b>	<b>Notes</b>
<b>Center Frequency</b>	2075.0 MHz <sup>8</sup>	400.5 MHz	
<b>Bandwidth</b>	0.1 MHz	0.04 MHz	The wider uplink bandwidth accommodates forward error correction (“FEC”).
<b>Data Rate</b>	38.4 kbps	38.4 kbps	Data rate is configurable from 1.2 kbps to 38.4 kbps.
<b>Modulation &amp; Coding</b>	2-GFSK (no coding)	2-GFSK (no coding)	Links may include FEC.
<b>Transmit Power</b>	12W	1.8W	
<b>Transmit Antenna</b>	3.0 m (dish)	Dipole (2x monopoles)	
<b>Transmit Antenna EIRP</b>	43 dBW	-9.1 dBW	
<b>Receive Antenna</b>	Patch (7 dBiC)	Yagi (2.5λ)	
<b>Receive Antenna G/T</b>	-32.8 dB/K	-11.6 dB/K	

**Table 2: Radio Frequency Plan**

3. Frequency Tolerance and Emission Limitations

Momentum 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

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<sup>8</sup> Both the identified center frequencies are representative frequency channels. As a result of coordination with federal operators, Momentum may select another channel within the identified frequency bands for its operations.

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.

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

Momentum's proposed thruster operations will not cause harmful radiofrequency interference 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.<sup>9</sup> The power flux density at the Earth's surface from 300 km, the estimated closest operational distance to the satellite, is far below the PFD threshold specified in the ITU Radio Regulations.<sup>10</sup> 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.

### **III. Waiver Requests**

The Commission may waive any of its rules if there is "good cause" to do so.<sup>11</sup> 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

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<sup>9</sup> See 47 CFR § 2.106.

<sup>10</sup> See ITU Radio Regulations 21.16.

<sup>11</sup> 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).

the rule.<sup>12</sup> 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.<sup>13</sup> 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.<sup>14</sup> 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’ 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

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<sup>12</sup> See *Northeast Cellular*, 897 F.2d at 1166.

<sup>13</sup> See *WAIT Radio*, 418 F.2d at 1157.

<sup>14</sup> See 47 C.F.R. § 2.106 n. US347.

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.<sup>15</sup> 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 provide sufficient information for the FCC to evaluate the satellite mission) is met and that grant of the requested waiver is justified.<sup>16</sup> Further, the FCC has granted similar applications for in-space transportation spacecraft in the recent past.<sup>17</sup>

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<sup>15</sup> 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).

<sup>16</sup> Consistent with FCC precedent, *see infra* note 17, 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.

<sup>17</sup> 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).

#### **IV. ITU Compliance**

Momentum 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

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*Counsel for Momentum Inc.*

Dated: February 21, 2019

**EXHIBIT 1**

**ITU Cost Recovery Letter**

## DECLARATION

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

Momentum Inc. (“Momentum”) 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. Momentum 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

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Address: 3050 Kenneth Street  
Santa Clara, CA 95054

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Sincerely,

*/s/ Philip Hover-Smoot*

Philip Hover-Smoot  
Regulatory Affairs  
Momentum Inc.

February 21, 2019