Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Momentus Inc.	)	File No. SAT-STA-20210210-00020
	)	
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 10, 2021 (as revised April 13, 2021)

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APPLICATION FOR SPECIAL TEMPORARY AUTHORITY

I. Introduction

By this application,[1] 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 at a specified final orbital destination.[2] VR-1 will operate in the S-band

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[1] At the request of the International Bureau ("Bureau") and to facilitate review and processing of the instant application, the applicant is resubmitting its narrative to provide a comprehensive document that includes the updates and corrections previously submitted in this proceeding. *See* Letter from Philip Hover-Smoot, Deputy General Counsel, Momentus Inc., to Karl Kensinger, Acting Chief, Satellite Division, International Bureau, Federal Communications Commission (filed March 29, 2021) (responding to Bureau inquiries regarding the VR-1 mission); Letter from Philip Hover-Smoot, Deputy General Counsel, Momentus Inc., to Karl Kensinger, Acting Chief, Satellite Division, International Bureau, Federal Communications Commission (filed March 5, 2021) (providing an ownership update); Letter from Tony Lin, Counsel to Momentus Inc., to Marlene H. Dortch, Secretary, Federal Communications Commission (filed February 25, 2021) (providing notice of a change in counsel). The applicant is also providing further details regarding the mechanics of the corporate transactions associated with the pending and previously described merger with Stable Road Acquisition Corp. *See* Exhibit 2.

[2] This application is materially identical to the previously submitted VR-1 application, IBFS File No. SAT-STA-20200609-00068 (including supplemental letters), except this version includes: an updated Orbital Debris Assessment Report ("ODAR") associated with a new launch (*see infra* at 4 and Exhibit 3); an update on National Oceanic and Atmospheric Administration ("NOAA") licensing (*see infra* at n.14); a revised ownership exhibit (*see* Exhibit 2); and a new International Telecommunication Union ("ITU") filing (*see infra* at § IV and Exhibit 1).

(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 Space Exploration Technologies Corporation ("SpaceX") Falcon-9 launch in June 2021, and the mission is expected to have a duration of 180 days, *i.e.*, from June 2021 to November 2021. Momentus will be communicating on the requested frequency bands, as necessary, for the full 180 days. It is possible that some portion of the 180 days will include time when VR-1 has a perigee lower than 300 km. For clarity, spacecraft disposal - *i.e.*, the period of time following the lowering of perigee to 300 km - is planned to begin prior to the 180-day mark. To the extent possible, Momentus will continue to conduct telemetry, tracking, and command ("TT&C") communications during the period when the perigee of VR-1 is below 300 km.

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 founding in 2017, Momentus has brought together a team of aerospace professionals, drawn from throughout the industry, united with the singular goal of changing how the world thinks about space transportation infrastructure. Through its revolutionary Vigoride spacecraft, each capable of transporting and delivering small satellites to tailored 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 lower-collision risk use of all orbits, including high-density orbits. Additionally, introducing the orbit flexibility of the Vigoride spacecraft into the existing commercial rideshare launch market can accelerate commercial space station deployments by expanding the orbital reach of existing launches, thereby increasing total ridership and contributing to lower launch prices. Cheaper, faster and smarter commercial space transportation has the capability to fundamentally change how space operators interact with on-orbit infrastructure. 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 Descriptions

1. Vigoride VR-1 Spacecraft

The Vigoride spacecraft is a self-propulsive, free-flying spacecraft designed to transport and deploy customer payloads. The Vigoride spacecraft is capable of the transportation and deployment of dozens of individual payloads. Customer spacecraft will be deployed after orbital insertion and prior to any orbit raising maneuvers. For the initial mission, Vigoride VR-1 will be transporting five (5) individual payloads (individually, "Payload 1" through "Payload 5," and collectively, the "Payloads"), on behalf of four (4) customers (collectively, the "Customers"). Table 1 below provides a summary of the payloads and customer information.

Payload:	Launched on behalf of:	Licensing Jurisdiction:	Size	Mass
AURORASAT[3]	Aurora Propulsion Technologies Oy	Finland	1.5U	2.0kg
LABSAT	SatRevolution	Poland	3.0U	4.0kg
STEAMSAT[4]	Steamjet Space Systems Ltd.	United Kingdom	1.5U	1.8kg
SWIFTVISION	SatRevolution	Poland	3.0U	4.0kg
VZLUSAT-2	SpaceManic CZ s.r.o.	Czech Republic	3.0U	4.4kg

Table 1: VR-1 Customer Payloads

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[3] AuroraSat has onboard propulsive capability.

[4] SteamSat has onboard propulsive capability.

All Payloads are commercial customer satellites. Furthermore, each customer is contractually obligated to obtain all necessary authorizations for operation of its spacecraft prior to integration with VR-1 and the launch vehicle, and Momentus has confirmed that each customer has all the necessary authorizations. If necessary, and in order to meet the VR-1 launch schedule, Momentus may replace a customer spacecraft with a mass dummy. Any such mass dummies would simulate the mechanical interfaces and mass of the customer spacecraft and allow Momentus to conduct a technology demonstration. Momentus, however, would not deploy the mass dummy in orbit. The casualty risk assessment in the ODAR (see attached Exhibit 3) includes a scenario in which mass dummies would remain on board the spacecraft throughout the mission and during re-entry. The mass dummies will be composed of aluminum and designed for demise. The ability to replace any customer satellite with a mass dummy is key to the ongoing certification of the VR-1 mass properties to the launch service provider. For the avoidance of doubt, should a representative mass be substituted for a customer payload, that representative mass would not be deployed on orbit.

The spacecraft is propelled primarily by a novel microwave electrothermal thruster (“MET”), which uses non-toxic and low-pressurized water propellant to provide orbit transfers. Momentus’ innovative technology and propulsion system recently won a NASA iTech award.[5] Additionally, earlier this year, Momentus successfully completed a Phase I SBIR contract in collaboration with the United States Air Force (AFWERX) and Air Force Research Lab (AFRL)

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[5] *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).

to accelerate innovations for in-space transportation services and satellite upper stage technologies.

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, via commercial ground stations, using encrypted links. Additional information on the Ground Segment is in section B.4. below.

VR-1 has a planned launch on a Falcon-9 rideshare in June 2021. VR-1 will be affixed directly to the Falcon-9 and deployed into a targeted 525 km (±25 km) circular sun-synchronous orbit with approximately a ~98 degree inclination.[6] After separation from the launch vehicle, VR-1 will undergo commissioning and, upon completion, will deploy Payloads 1 through 5. Subsequent to payload deployment, VR-1 will conduct orbit-raising maneuvers to a targeted maximum 570 km circular sun-synchronous orbit with a ~98 degree inclination. *See* Table 3 below (summarizing the relevant orbital parameters for the Payloads and VR-1).

As an integral part of the orbit raising concept of operations, 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. VR-1 will operate with an approximately 18% margin of propellant, in addition to the propellant necessary to achieve the operational concept (including lowering of perigee to 300 km at end of mission). Momentus contemplates that this reserve will serve as support for all contingencies during the VR-1 mission, including orbital debris avoidance maneuvers. To clarify, VR-1's capacity for

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[6] For the purposes of this application, Momentus assumed a 550 km maximum insertion orbit. In the event of the launch vehicle operator selecting an alternative insertion orbit, Momentus will notify the FCC.

“real time collision avoidance and orbital maintenance maneuvers,” is constrained by the availability of uplink and downlink opportunities and thus such maneuvers may not be available in real time during those parts of orbit that are outside of ground station range. The amount of reserve remaining following an orbital debris avoidance maneuver would depend on the nature and duration of the avoidance maneuver. Anecdotally, however, a single kg of propellant can power many kilometers of orbital adjustment. Additionally, there is historical evidence that collision avoidance maneuvers are rare, and conjunction avoidance is usually accomplished with orbital adjustments of less than 1 km. Accordingly, Momentus expects to have sufficient propellant reserves to conduct multiple contingency operations, including during spacecraft disposal.

As demonstrated in the attached ODAR (see Exhibit 3), a 570 km circular sun-synchronous orbit would be the worst-case scenario in the assessment of orbital debris risk, and VR-1 would re-enter the Earth’s atmosphere in approximately 17 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 a target of 300 km altitude. Momentus intends to reserve propellant so that there will be sufficient propellant to execute the de-orbit maneuvers necessary to achieve the targeted 300 km perigee. At a 570 (maximum) x 300 km orbit, Momentus calculates that VR-1 will de-orbit within approximately 2 years. Naturally, if VR-1 does not reach a 570 km circular orbit, the VR-1 de-orbit period will be compressed further following completion of the de-orbit maneuver.

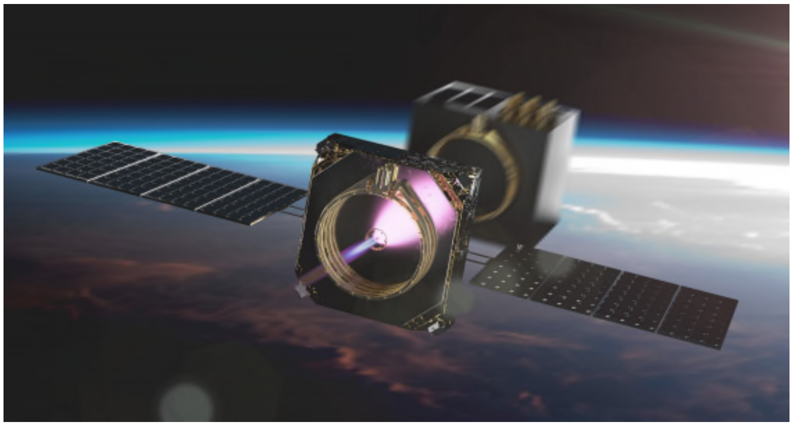

Figure 1: Artist's rendering of Vigoride deploying a customer spacecraft

2. The Momentus "Plaza Deck"

As part of the VR-1 mission, Momentus will also be deploying a number of additional payloads from a fixed "plaza deck," which will be permanently affixed to the Falcon-9.[7] The "plaza deck" does not require use of spectrum and is not subject to the spectrum request in this application. Nonetheless, Momentus is providing this information for completeness.

On the "plaza deck," one ISILaunch cubesat deployer and three Alba Orbital PocketQube picosat deployers will be mounted.[8] Customers being deployed from the "plaza deck" are all contractually obligated to obtain all necessary authorizations for operation of its spacecraft or payload prior to integration with the plaza deck and the launch vehicle. Momentus has confirmed that each customer has all necessary authorizations. As of the filing of this application, all payloads currently under contract with Momentus to be deployed from the Plaza Deck can be found in Table 2, below.

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[7] VR-1 will also be deployed from the plaza deck.

[8] Momentus will fly mass dummies for three of the four ISILaunch cubesat deployers the previous application identified.

Payload:	**Launched on behalf of:**	**Licensing Jurisdiction:**
ISILaunch Quadpack	Innovative Space Logistics, B.V.	Netherlands
NUTSAT-0	Gran Systems Co., Ltd.	Taiwan
Alba PocketQubes (#3)	Alba Orbital Deutschland, U.G.	Germany

Table 2: Plaza Deck Payloads

B. Technical Specifications

1. Orbital Parameters

The VR-1 concept of operations is as follows[9]:

1. Launch vehicle arrives at initial orbit (maximum 550 km altitude circular sun-synchronous orbit)[10]
2. VR-1 separates from launch vehicle
3. VR-1 undergoes commissioning and preliminary testing
4. VR-1 deploys Payloads 1 through 5
5. VR-1 conducts orbit raising maneuvers to second orbit (maximum 570 km circular sun-synchronous orbit, based on a planned 20 km raise from a notional maximum 550 km initial orbit)
6. VR-1 performs detailed system functional testing
7. VR-1 conducts de-orbit maneuvers (targeting 300 km perigee)

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[9] VR-1 concept of operations is in addition to the deployment of Momentus customer payloads from the plaza deck.

[10] SpaceX reports a planned injection orbit of 525 km (± 25 km).

	Insertion and Payloads 1 through 5 Orbit	**VR-1 Transfer Orbit**	**VR-1 End-of-Life Orbit**
Apogee Altitude	550 km (max)	570 km (max)	570 km (max)
Perigee Altitude	550 km (max)	570 km (max)	300 km[11]
Inclination	~98° (Sun-Synchronous)	~98° (Sun-Synchronous)	~98°
Period	96 mins	96 mins	90-96 mins
Argument of Perigee	N/A	N/A	N/A
Local Time of the Ascending Node (LTAN)	~1:30	~1:30	~1:30
Maximum De-Orbit Life	VR-1[12] 21 years	VR-1[13] 17 years	VR-1 2 years

Table 3: 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 4 below. The use of those frequencies will be primarily for TT&C. However, Momentus will also downlink imagery generated from an on-board camera to confirm successful deployment of the Payloads.[14] Momentus is aware that there are federal and other operations in these frequency

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[11] The target perigee as a result of de-orbit maneuvers is expected to be 300 km.

[12] 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.

[13] This is the de-orbit duration if VR-1 has a propulsion system failure after raising the orbit to 570 km altitude.

[14] Momentus has obtained a commercial remote sensing license from NOAA for the operations of imaging sensors and intends to comply with all necessary NOAA regulatory requirements. *See* 15 C.F.R. Part 960.

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[15]	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 4: Radio Frequency Plan

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[15] 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. Moreover, Momentus previously coordinated the use of these same frequencies for the VR-1 mission.

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.[16] The peak gain value for the transmit beam is 5.15 dB. The peak gain value for the receive beam is 6 dB.

The mission is expected to have a duration of 180 days, *i.e.*, from June 2021 to November 2021. Momentus will be communicating on the requested frequency bands, as necessary, for the full 180 days. It is possible that some portion of the 180 days will include time when VR-1 has a perigee lower than 300 km. For clarity, spacecraft disposal - *i.e.*, the period of time following the lowering of perigee to 300 km - is planned to begin prior to the 180-day mark. To the extent possible, Momentus will continue to conduct TT&C communications during the period when the perigee of VR-1 is below 300 km.

3. 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-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"), via their "Leaf Key" ground segment as a service solution, as the ground segment provider. Leaf Space currently has operational ground stations in Europe. Leaf Space received a license from the Italian Ministry of Economic Development ("MISE") on April 4, 2020 to operate their Vimercate (Milan area) ground station in support of the VR-1 mission within the parameters

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[16] *See* Exhibit 4.

described herein. Leaf Space has also obtained a license for operation of the VR-1 spacecraft using an additional ground station located in Cork, Ireland. Communications between Momentus HQ and Leaf Space will be protected by levels of encryption appropriate to secure control over the VR-1. TT&C transmissions will be encrypted. Table 5 below identifies the ground stations from which Leaf Space plans to communicate with the VR-1 spacecraft.

Location	**Latitude (°N)**	**Longitude (°E)**	**Status**
Vimercate, Italy	45.59	9.36	Operational
Cork, Ireland	51.90	-8.48	Operational

Table 5: Ground Station

5. Microwave Electrothermal Thruster

VR-1 uses a radiofrequency generator that emits electromagnetic energy at a maximum theoretical power level of 40 watts (16.53 dBW) to operate the thruster. The electromagnetic emissions of the VR-1 thruster would not exceed 15 uV/m at a distance of 300 meters. Our calculations indicate the thruster is expected to produce electromagnetic emissions at levels less than 10 uV/m at a distance of 300 meters.

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 location of the generator and the application of shielding mitigates the radiation of emissions outside of the injector. The emission frequency generated by the RF Power Module ("RPM") is controlled and can be adjusted over the frequency range 10.25 to 10.60 GHz as needed. 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 ITU regions.[17] 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.[18] 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.[19]

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[17] *See* 47 C.F.R. § 2.106.

[18] *See* ITU Radio Regulations 21.16.

[19] Due to the operation of the equipment as part of the spacecraft, Momentus believes the VR-1 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.

III. Waiver Requests

The Commission may waive any of its rules if there is "good cause" to do so.[20] 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.[21] 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.[22] 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.

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.[23] As discussed above, Momentus plans to use ground stations in Italy and Ireland, operated by Leaf Space, to communicate with VR-1 for the provision of in-space transportation services. Accordingly, to the extent necessary, Momentus

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[20] *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).

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

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

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

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.[24] 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.[25] 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 on a long-term basis. Accordingly, the request to use these frequencies should be considered outside of the 400.15-401 MHz processing round.

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[24] Such use will also include transmission of limited imagery of the Payloads during deployment primarily to ensure mission safety and success.

[25] *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).

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. Further, the FCC has granted similar applications for in-space transportation spacecraft in the recent past.[26]

In any event, to the extent necessary, Momentus provides responses to questions 29-34 and 36-40 of the Form 312 and attaches a Schedule S.[27] Section 310(b)(4) of the Communications Act of 1934, as amended, establishes certain limitations on indirect foreign ownership and voting of certain common carrier and broadcast licensees. By definition, these limitations do not apply to the non-broadcast, noncommon carrier operations of Momentus, as proposed in this application.

- Question 29: NO
- Question 30: N/A. See discussion above.
- Question 31: N/A. See discussion above.
- Question 32: N/A. See discussion above.
- Question 33: N/A. See discussion above.
- Question 34: N/A. See discussion above.
- Question 36: NO

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[26] *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).

[27] *See also* Exhibit 2 (providing ownership information).

- Question 37: NO
- Question 38: NO
- Question 39: NO

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

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Dated: February 10, 2021 (as revised April 13, 2021)

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:	+1-415-254-1295

Sincerely,

/s/ Philip Hover-Smoot

Philip Hover-Smoot
Deputy General Counsel
Chief Ethics & Compliance Officer
Momentus Inc.

February 10, 2021

EXHIBIT 2

Ownership Information

Momentus Inc. ("Momentus") is a privately held corporation.

Listed below are the entities that currently have a 10% or greater equity and/or voting interest in Momentus: [1]

1. **Mikhail Kokorich directly and/or indirectly**
   c/o Momentus Inc.

   3050 Kenneth Street

   Santa Clara, CA 95054

   Ownership Interest: approximately 19% (see discussion below)

   Voting Interest: approximately 47% (see discussion below)

   Nationality: Russia

2. **Olga Khasis directly and/or indirectly**[2]
   16047 Collins Avenue, Unit 1603

   Sunny Isles Beach, Florida 33160

   Ownership Interest: approximately 17% (see discussion below)

   Voting Interest: approximately 36% (see discussion below)

   Nationality: U.S.

3. **Dakin Sloss**
   General Partner, Prime Movers Lab ("PML")

   PO Box 12829

   Jackson, WY 83002

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[1] The ownership percentages listed in this application are fully diluted percentages. All voting interests listed in this application are based on outstanding stock, taking into account that certain classes of stock are "high vote" stock with 10 votes per share.

[2] Ms. Khasis is the wife of Momentus' co-founder Lev Khasis, who is a Russian citizen and a U.S. permanent resident.

PML Ownership Interest: approximately 29%

PML Voting Interest: approximately 10%

OFFICERS, DIRECTORS, AND SENIOR LEADERS

All of the directors, officers, and senior leaders of Momentus may be reached at the following address:

c/o Momentus Inc.
3050 Kenneth Street
Santa Clara, CA 95054

CEO, Director	*Dawn Harms*[3]
President	*Dr. Fred Kennedy*
Director, Chairman	*Dakin Sloss*
Director	*Vince Deno*
General Counsel	*Alexander Fishkin*
Assoc. General Counsel	*Philip Hover-Smoot*
CFO	*Jikun Kim*
CTO	*Rob Schwarz*
Controller	*Temitope Oduozor*

Further Discussion

Momentus recently underwent a significant change in our senior leadership. Effective January 23, 2021, Mr. Kokorich, one of the co-founders of Momentus, resigned as CEO and as a member of Momentus's Board of Directors. Dawn Harms, who was previously the company's Chief Revenue Officer, has been appointed as interim CEO and has been elected as a member of the Board of Directors.

In parallel with Mr. Kokorich's resignation, and with the express goal of fully addressing the U.S. government's national security concerns, Mr. Kokorich and Ms. Khasis and their related

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[3] Each senior leader or director listed is a U.S. citizen. Additionally, the following leaders hold current or unassigned but activatable Personal Security Clearances: Dawn Harms (TS/SCI), Fred Kennedy (TS/SCI), Philip Hover-Smoot (S), and Rob Schwarz (S).

entities are committing to divest all shares they hold in Momentus directly or indirectly. Mr. Kokorich and entities related to him plan to give up their voting rights in Momentus by placing all Momentus shares they own into trusts whereby a proxyholder designated by Momentus will vote such shares and these shareholders will cooperate with Momentus by agreeing to the divestiture of their shares by the trusts. The proxyholder will vote all of Mr. Kokorich’s shares in his or her sole discretion. The voting interest held by Mr. Kokorich (directly and indirectly) is planned to be assigned to the interim CEO of the Company, Dawn Harms. After his and his related entities' shares are moved into trusts, Mr. Kokorich will not be able to exert any control with respect to Momentus. Prior to the placement of the shares in trust, Mr. Kokorich and his related entities are committing to refrain from voting their shares or taking any action to influence Momentus. The Momentus shares owned by Ms. Khasis also will be moved to a trust to be divested and the voting of such shares will be controlled by a designated proxyholder who is a U.S. citizen.

Momentus plans to merge with Stable Road Acquisition Corp. (Nasdaq ticker symbol: SRAC) (“SRAC”), which is a publicly traded special purpose acquisition company and will be listed as a publicly traded company (the “SPAC Transaction”). After the closing, no persons will have any board appointment or nomination rights. Momentus and SRAC have agreed that the six-member board will consist of (1) the interim CEO of Momentus, Dawn Harms (who is a U.S. citizen), (2) Brian Kabot, the Chairman and Chief Executive Officer of SRAC (who is a U.S. citizen), (3) three independent directors, Vince Deno, David Siminoff, and Chris Hadfield (Mr. Deno and Mr. Siminoff are U.S. citizens and Mr. Hadfield is a Canadian citizen); and (4) a sixth independent director who has not yet been identified, which were jointly agreed between

Momentus and SRAC, subject to approval by a majority vote of SRAC's shareholders. Momentus will update the Commission of changes.

Pursuant to the merger agreement, as amended on March 5, 2021 (as it may be further amended from time to time, the "Merger Agreement"), by and among Momentus, SRAC, Project Marvel First Merger Sub, Inc., a Delaware corporation and a direct, wholly owned subsidiary of SRAC ("First Merger Sub"), and Project Marvel Second Merger Sub, LLC, a Delaware limited liability company and a direct, wholly owned subsidiary of SRAC ("Second Merger Sub"), First Merger Sub will merge with and into Momentus (the "First Merger"), with Momentus being the surviving corporation of the First Merger. Immediately following the First Merger, the surviving corporation will merge with and into Second Merger Sub, with Second Merger Sub being the surviving company of the Second Merger. Following the mergers, SRAC will be renamed Momentus Inc. and such combined operating company would continue to have its Class A common stock and public warrants listed on Nasdaq and trade under the ticker symbols "MNTS" and "MNTSW", respectively.

Accordingly, upon completion of the SPAC Transaction, the FCC application or license, if granted by that date, will be held by Second Merger Sub and the new Momentus Inc. will be the direct parent company of the FCC applicant or licensee, as applicable.

EXHIBIT 3

Orbital Debris Assessment Report

Vigoride-1 Spacecraft
Orbital Debris Assessment Report (ODAR)

V4

04/07/2021

Momentus Inc.

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Document contains no ITAR or otherwise restricted data.

DAS Software Version used in Analysis: v3.1.0

Revision History

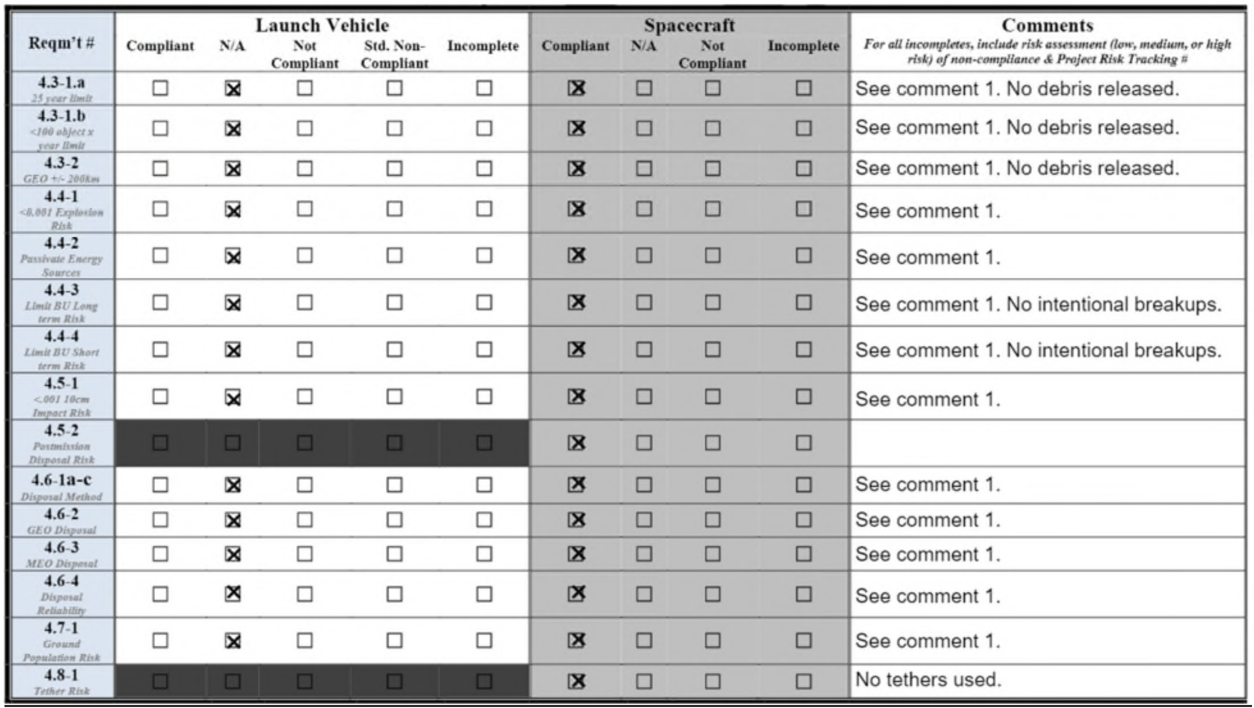
Revision Number	Updates	Page #	Author	Date
1	Initial Release	All	Sam Avery	6/8/20
2	Including DAS 3.1.0 software	All	Sam Avery	8/6/20
3	Minor updates based on launch date shift	All	Sam Avery	2/9/21
4	Correct CONOPS statements and add worst-case large object collision risk analysis	5 and Annex A	Sam Avery	4/7/21

Table of Contents

Sam Avery

Sam Avery
Regulatory Technical Lead, Vigoride-1
Momentus

Orbital Debris Self-Assessment Evaluation



Reqm't #	Launch Vehicle					Spacecraft				Comments
	Compliant	N/A	Not Compliant	Std. Non-Compliant	Incomplete	Compliant	N/A	Not Compliant	Incomplete	*For all incompletes, include risk assessment (low, medium, or high risk) of non-compliance & Project Risk Tracking #*
4.3-1.a *25 year limit*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1. No debris released.
4.3-1.b *<100 object x year limit*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1. No debris released.
4.3-2 *GEO +/- 200km*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1. No debris released.
4.4-1 *<0.001 Explosion Risk*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.4-2 *Passivate Energy Sources*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.4-3 *Limit BU Long term Risk*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1. No intentional breakups.
4.4-4 *Limit BU Short term Risk*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1. No intentional breakups.
4.5-1 *<.001 10cm Impact Risk*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.5-2 *Postmission Disposal Risk*	☐	☐	☐	☐	☐	☒	☐	☐	☐	
4.6-1a-c *Disposal Method*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.6-2 *GEO Disposal*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.6-3 *MEO Disposal*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.6-4 *Disposal Reliability*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.7-1 *Ground Population Risk*	☐	☒	☐	☐	☐	☒	☐	☐	☐	See comment 1.
4.8-1 *Tether Risk*	☐	☐	☐	☐	☐	☒	☐	☐	☐	No tethers used.

Comment 1. This ODAR analyzes only VR-1 and provides representative information regarding the customer payloads. The launch vehicle and other launch vehicle payloads are not considered in this ODAR.

Assessment Report Format

ODAR Technical Sections Format Requirements: This ODAR follows the format recommended in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in sections 2 through 8 for the Vigoride-1 ("VR-1") satellite. Sections 9 through 14 of the NASA standard apply to the launch vehicle ODAR and are not covered here.

I. Program Management and Mission Overview

Project Manager:

- Aliki Loper-Leddy

Foreign Government or space agency participation:

- None

Schedule of Upcoming Mission Milestones:

- Launch – June 2021

Mission Overview:

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 founding in 2017, Momentus has brought together a team of aerospace professionals, drawn from throughout the industry, united with the singular goal of changing how the world thinks about space transportation infrastructure. Through its revolutionary Vigoride spacecraft, each capable of transporting and delivering small satellites to tailored 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 lower-collision risk use of all orbits, including high-density orbits. Additionally, introducing the orbit flexibility of the Vigoride spacecraft into the existing commercial rideshare launch market can accelerate commercial space station deployments by expanding the orbital reach of existing launches, thereby increasing total ridership and contributing to lower launch prices. Cheaper, faster and smarter commercial space transportation has the capability to fundamentally change how space operators interact with on-orbit infrastructure.

This ODAR evaluates the Momentus initial demonstration mission, Vigoride-1 ("VR-1"), which is planned to launch on a SpaceX Falcon-9 rocket in June 2021. For the demonstration mission, VR-1 will exhibit the capacity to transport and deploy multiple payloads. Each customer satellite payload is a commercial smallsat individually licensed and authorized to operate by each respective national jurisdiction.[1] The necessary de-orbit and debris analysis for customer satellite payloads will be addressed through the licensing process for the relevant payload.[2]

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[1] General information regarding the customer satellites is provided in Table 1 in the application narrative.

[2] In the event a customer payload is unable to be launched, Momentus will launch VR-1 with a representative mass, and such mass shall not be deployed.

Launch Vehicle:

- Falcon-9

Expected Launch Site:

- Cape Canaveral Space Launch Complex (SLC-40 or SLCE-4E)

Operational Mission Duration:

- Planned for 180 days.

The VR-1 concept of operations is as follows:

1. Launch vehicle arrives at initial maximum orbit (550 km altitude circular sun-synchronous)[3]
2. VR-1 separates from launch vehicle
3. VR-1 undergoes commissioning and preliminary testing
4. VR-1 deploys Payloads 1 through 5
5. VR-1 conducts orbit raising maneuvers to second orbit (max. 570 km circular sun-synchronous orbit, based on a planned 20 km raise from a notional max 550 km initial separation)
6. VR-1 performs detailed system functional testing
7. VR-1 conducts de-orbit maneuvers (targeting 300 km perigee)

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[3] SpaceX reports a planned insertion orbit of 525 km (± 25 km), thus initial maximum altitude described in the concept of operations above indicated maximum injection altitude of 550 km.

Table 1: Orbital Parameters

	Insertion and Payloads 1 through 5 Deployment	VR-1 Transfer Orbit	VR-1 End-of-Life Orbit
Apogee Altitude	550 km (max)	570 km (max)	570 km (max)
Perigee Altitude	550 km (max)	570 km (max)	300 km[4]
Inclination	~98° (Sun-Synchronous)	~98° (Sun-Synchronous)	~98°
Period	96 mins	96 mins	90-96 mins
Argument of Perigee	N/A	N/A	N/A
Local Time of the Ascending Node (LTAN)	~1:30	~1:30	~1:30
Maximum De-Orbit Life	VR-1 21 years[5]	VR-1 17 years[6]	VR-1 2 years

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[4] The target perigee as a result of de-orbit maneuvers is 300 km.

[5] This is the de-orbit duration if VR-1 has both a propulsion system failure *and* a solar array deployment failure after deployment from the launch vehicle.

[6] This is the de-orbit duration if VR-1 has a propulsion system failure after raising the orbit to 570 km altitude.

II. Spacecraft Description

Physical Description:

VR-1 has the following subsystems: Propulsion System, Structures, Mechanisms, Electric Power System, and Avionics.

VR-1 includes a primary and a secondary structural assembly with: Propellant Tanks, MET, Reaction Control System thrusters, Solar Array Assemblies, a payload adapter ring for interfacing with the “plaza deck” for deployment[7] and, thereby, the launch vehicle, and one 12U cubesat deployer.

The VR-1 spacecraft bus includes two spring-loaded UHF antennas which are deployed after separation from the launch vehicle by a burn wire. In addition, VR-1 includes two 4-panel 150W deployable solar arrays which are deployed using a frangibolt Hold Down and Release Mechanism (HDRM). Both of these deployments are controlled by a software timer via the flight computer.

The Payloads are fully stowed in their deployers and their power is inhibited prior to on-orbit deployment. The Payloads will follow the form and mass characteristics of a standard cubesat of the relative U-size of the payload. The VR-1 spacecraft platform components all have their power inhibited until launch vehicle separation occurs.

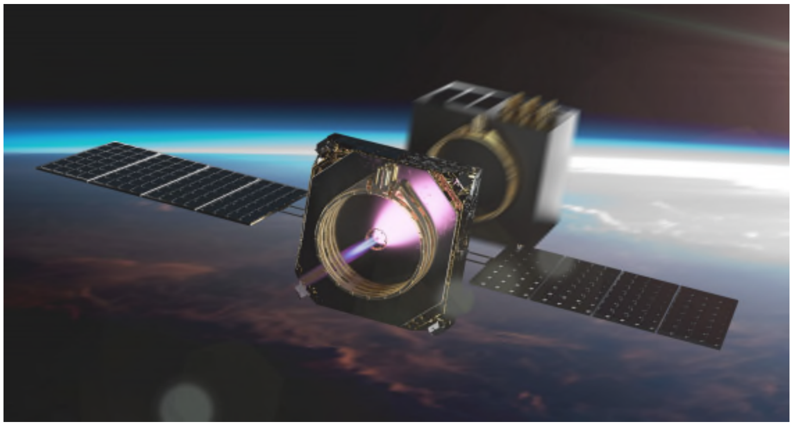

Figure 1. Artist rendering of Vigoride deploying a customer spacecraft.

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[7] A detailed description of the plaza deck is described in the narrative exhibit.

Table 2. General Spacecraft Description

Criteria	Description	Notes
Spacecraft Total Launch Mass	161 kg	Includes 6 kg of propellant.
Spacecraft Launch Dry Mass	155 kg	
Propulsion System	MET and resistojet reaction control thrusters. See *Propulsion System Description*.	Propulsion system operates using non-toxic and low-pressure liquid water propellant.
Body Dimensions	0.62x0.69x0.62 m^3	
Deployed Solar Array Dimensions	3.5x0.64x0.03 m^3	Dimensions per solar array wing.
Identification of all Fluids	• Liquid/vapor water mixture (propellant) • Nitrogen (tank pressurant) • Helium (tank pressurant) See *Fluids Description*.	
Fluids in Pressurized Batteries	None. VR-1 uses unpressurized lithium ion cells.	
Attitude Determination and Control	Attitude Determination • Star Tracker • Sun Sensors • Magnetometers • Gyroscope Attitude Control • Magnetic Torque Rods	

	- Reaction Wheels - Reaction Control Thrusters See *Attitude Determination and Control System Description*.	
Range Safety or Pyrotechnic Devices	None	
Electrical Generation and Storage System	Two 150W solar array wings for power generation. One Lithium-Ion 7S1P battery (~28V) and one Lithium-Ion 1S4P battery (~4.2V) are included and charged prior to launch vehicle integration. A separate failsafe deployment mechanism includes a Lithium-Ion 1S1P battery (~4.2V).	
Other Stored Energy	- Solar array spring energy stored in hinges. - Clampband separation system spring energy. - CubeSat deployer hinged door spring energy.	
Radioactive Materials	Not applicable.	

Propulsion System Description

The Vigoride propulsion system energizes distilled water into plasma using RF microwave energy. The plasma is expelled out of the thruster using a nozzle to produce thrust at a specific impulse (Isp) exceeding traditional chemical propulsion systems. The expected thrust and Isp will vary with input power levels but will not exceed 15 mN. The VR-1 mission will nominally include 6 ±1 kg of liquid water propellant at launch. The 6 kg of water is roughly split into two parts: 4 kg total in two diaphragm tanks; and 2 kg total in two prototype propellant tanks. The maximum expected total impulse is approximately 25 kNs.

In addition, there are four experimental reaction control thrusters with estimated maximum thrust of 5 mN and specific impulse of 80 seconds. These reaction control thrusters use the same stored liquid water as a propellant.

Fluids Description

The propulsion system includes two diaphragm tanks with liquid water propellant pressurized using inert gaseous nitrogen. Each diaphragm tank is expected to include 2 kg of propellant. In addition, there are two prototype propellant tanks filled with water propellant and pressurized at launch using inert gaseous helium. These prototype propellant tanks are expected to include 1 kg of propellant. At spacecraft integration the diaphragm tanks are pressurized to 44 psi at 68°F, one prototype propellant tank at 50 psi at 140°F, and another prototype propellant tank at the vapor pressure of water at 3 psi at 140°F. The tanks are expected to remain within 20% of these pressures during transportation to the launch site, during launch, and post launch until thruster operations.

At the end of the mission, following a de-orbit maneuver, the propellant flow valve will be fully opened to allow all propellant and pressurant to vent into space and remove thrusting capability from the system. The spacecraft will be oriented such that any resultant thrust from the drain operations will result in a lower orbital altitude.

Attitude Determination and Control System Description

The VR-1 spacecraft includes 3-axis control with magnetic torque rods for coarse pointing and detumbling, reaction wheels for fine control (1° pointing accuracy), and experimental reaction control thrusters. For attitude determination, the spacecraft includes a star tracker, sun sensors, magnetometers, and a gyroscope, providing nominally >3° pointing knowledge.

- A sun tracking mode that is optimized for solar power generation from the satellite. The spacecraft's body will be oriented in two axes, and on-board Solar Array Drive Assemblies (SADAs) will rotate the panels along the third axis.
- A targeted tracking mode will allow the thrust axis to be pointed in any direction in inertial space.

III. Spacecraft Debris Released during Normal Operations

Payload Re-Contact Mitigation

Momentus will plan to support at least three re-contact mitigation strategies, for deployments from VR-1:

1. Payload deployments will be spaced apart by at least 90 minutes, or 1 full orbit.
2. Payload deployments will alternate between along-track deployment with the velocity vector and with the anti-velocity vector.
3. On-board propulsion may also be used for maneuvers to minimize the risk of re-contact.

Persistent Liquids and Propellant-Related Debris

During primary mission operations, any water released into space through the MET or the reaction control thrusters will be vaporized at sufficiently high temperature (>500K) to prevent the formation of debris. In the off-nominal case of a leak or flow of liquid water, there is potential for the creation of small water ice crystals. Any generated water ice crystals are expected to sublimate within minutes of exposure to sunlight.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.1.1)

- **4.3-1, Mission Related Debris Passing Through LEO:** COMPLIANT
- **4.3-2, Mission Related Debris Passing Near GEO:** COMPLIANT

IV. Intentional Breakups and Potential for Explosions

Potential causes of spacecraft breakup during deployment and mission operations:

There are two potential scenarios that could potentially lead to a breakup of the satellite:

1) Rupture of the propellant tank (H_20, N_2 , He)
2) Lithium-ion battery cell failure

Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion:

- In-mission failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. The battery safety systems discussed in the failure modes and effects analysis ("FMEA") (see requirement 4.4-1 below) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to an explosion.

Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions:

- There are no planned breakups.

List of components which shall be passivated at End of Mission including method of passivation and amount which cannot be passivated:

- Twelve (12) Lithium-ion battery cells.

Rationale for all items which are required to be passivated, but cannot be due to their design:

- None.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:

Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:

For each spacecraft and launch vehicle orbital stage employed for a mission, the program or project shall demonstrate, via failure mode and effects analyses or equivalent analyses, that the integrated probability of explosion for all credible failure modes of each spacecraft and launch vehicle is less than 0.001 (excluding small particle impacts) (Requirement 56449).

- **Compliance statement:**
  - Required Probability: 0.001.
  - Expected probability: 0.000.

Supporting Rationale and FMEA details:

- **Pressure Tank Explosion:**
    - **Effect:** A rupture of one propellant tank would release water and nitrogen or helium. Due to the low pressure (50 psi), the penetrating energy of any debris would be relatively low. The tank is enclosed in the solid aluminum structural walls of the spacecraft. These aluminum walls would contain any released debris within the body of the spacecraft.
    - **Probability:** Very low. A structural failure of the tank would need to occur, and the mechanisms by which these failures occur are very well understood. The factor of safety for all vessels is 2, and the surrounding structure has a higher factor of safety.
- **Battery explosion:**
    - **Effect:** All failure modes below might result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy and multiple enclosures surrounding the batteries.
    - **Probability:** Extremely Low. Estimated to be less than 0.01% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).
    - **Failure Mode 1:** Internal short circuit.
        - *Mitigation 1:* All of the following testing has or will be performed prior to flight: protoflight level sine burst, sine, and random vibration testing in all three axes, thermal vacuum cycling and extensive functional testing, system rate-limited charge and discharge cycles, and subsystem and component level functional testing. The testing helps prove that no internal short circuit sensitivity exists.
        - *Combined Faults Required for Realized Failure:* Environmental testing AND functional charge / discharge tests must both be ineffective in discovery of the failure mode.
    - **Failure Mode 2:** Internal thermal rise due to high load discharge rate.
        - *Mitigation 2:* Battery cells were tested in lab for high load discharge rates in a variety of flight-like configurations to determine the feasibility of an out-of-control thermal rise in the cell. Cells are also tested in a hot, thermal vacuum environment (5 cycles at 50°C, then to -20°C) in order

        to test the upper limit of the cells' capability. No failures were observed or identified via satellite telemetry or via external monitoring circuitry.
    - *Combined Faults Required for Realized Failure:* Spacecraft thermal design must be incorrect AND external over-current detection and disconnect function must fail to enable this failure mode.
- **Failure Mode 3:** Excessive discharge rate or short-circuit due to external devices failure of terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).
    - *Mitigation 3:* Qualification testing of short circuit protection on each external circuit, design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, and observation of such other mechanical failures by protoflight level environmental tests (sine burst, random vibration, thermal cycling, and thermal-vacuum tests).
    - *Combined Faults Required for Realized Failure:* An external load must fail/short-circuit AND external over-current detection and disconnect function must all occur to enable this failure mode.
- **Failure Mode 4:** Inoperable vents.
    - *Mitigation 4:* Battery venting is not inhibited by the battery holder design or the spacecraft design. The battery can vent gases to the external environment.
    - *Combined Faults Required for Realized Failure:* The cell manufacturer OR the satellite integrator fails to install proper venting.
- **Failure Mode 5:** Crushing.
    - *Mitigation 5:* This mode is negated by spacecraft design with no moving parts in the proximity of the batteries.
    - *Combined Faults Required for Realized Failure:* A catastrophic failure must occur in an external system AND the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit AND the satellite must be in a naturally sustained orbit at the time the crushing occurs.
- **Failure Mode 6:** Low level current leakage or short-circuit through battery or short-circuit through battery pack case or due to moisture-based degradation of insulators.
    - *Mitigation 6:* The battery holder and case design are made of non-conductive plastic and operation in vacuum ensures that no moisture can affect insulators.

        - *Combined Faults Required for Realized Failure:* Abrasion or piercing failure of circuit board coating or wire insulators AND dislocation of battery packs AND failure of battery terminal insulators AND failure to detect such failures in environmental tests must occur to result in this failure mode.
    - **Failure Mode 7:** Excess temperatures due to orbital environment and high discharge combined.
        - *Mitigation 7:* The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that the batteries do not exceed normal allowable operating temperatures under a variety of modeled cases, including worst case orbital scenarios. Analysis shows these temperatures to be well below temperatures of concern for explosions.
        - *Combined Faults Required for Realized Failure:* Thermal analysis AND thermal design AND mission simulations in thermal-vacuum chamber testing AND over-current monitoring and control must all fail for this failure mode to occur.

Requirement 4.4-2: Design for passivation after completion of mission operations while in orbit about Earth or the Moon:

Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or postmission disposal or control to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

- Compliance statement:
    - VR-1 includes the ability to fully disconnect the Lithium Ion cells from the charging current of the solar arrays. At End-of-Life, this feature can be used to completely passivate the batteries by removing all energy from them. In the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of these small batteries is such that while the spacecraft could be expected to vent gases, the debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.
    - As discussed above in the propulsion system section, all energy will be released from the propulsion system prior to spacecraft deactivation. The spacecraft will be oriented such that any thrust generated from propellant release results in an orbit lowering maneuver. All thruster valves will be opened until all

propellant and pressurant are completely released. No attempt will be made to activate the RF microwave element, which will result in a “cold gas” thruster firing.

Requirement 4.4-3: Limiting the long-term risk to other space systems from planned breakups:

- Compliance statement:
    - Not applicable. There are no planned breakups.

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups:

- Compliance statement:
    - Not applicable. There are no planned breakups.

V. Spacecraft Potential for On-Orbit Collisions

While the calculated risk of on-orbit collision with large debris or other operational space stations is low, Momentus shall monitor the VR-1 throughout the operational life of the space station to ensure real-time collision avoidance and orbital maintenance maneuvers are executed as needed.[8] Additionally, this monitoring shall assess, on an ongoing basis, the accuracy with which the targeted orbital parameters are to be maintained.[9] Furthermore, the proposed operation of the VR-1 does not rely on or otherwise necessitate coordination with any other operational space stations and no assessment of successful coordination with such an operator has been performed to date.

Requirement 4.5-1. Limiting debris generated by collisions with large objects when operating in Earth orbit:

- For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).
- **Large Object Impact and Debris Generation Probability:**
    - 2.9960E-5; COMPLIANT.

  Attached in Annex A to this ODAR, Momentus provides a worst-case calculation of large object collision risk for the VR-1, taking into account a scenario where the customer spacecraft remain onboard following orbit-raising. As demonstrated in the attached Annex, VR-1 remains compliant with this requirement.

Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:

- For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.01 (Requirement 56507).
- **Small Object Impact and Debris Generation Probability:**
    - 6.3335E-6; COMPLIANT

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[8] VR-1 is capable of adjusting orbits at speeds that support dynamic collision avoidance. This near real-time orbital adjustments is feasible only when VR-1 is capable of communication with the MOC and there is ground station availability.

[9] The Momentus assessment of the VR-1's accuracy for orbital parameter maintenance indicates performance will be within the following ranges: Apogee, ±1km; Perigee, ±200m; Inclination, <1%: and the Right Ascension of the Ascending Node(s), <1%.

Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:

- None are specifically required, but the propulsion system is expected to be used for a postmission de-orbit maneuver to decrease the time until atmospheric re-entry to less than 2 years. The flight computer, radio hardware, battery system, and control boards will be used to vent all propellant and to disconnect the battery from the solar array current.

VI. Spacecraft Postmission Disposal Plans and Procedures

Description of spacecraft disposal option selected:

- VR-1 will de-orbit naturally by atmospheric re-entry without any intervention. However, VR-1 will attempt a de-orbit maneuver to reduce the time to atmospheric re-entry to approximately two years.

Plan for any spacecraft maneuvers required to accomplish postmission disposal:

- No maneuvers are required for postmission disposal. However, VR-1 will attempt a de-orbit maneuver as a proof of concept for future missions, as explained in the concept of operations (p. 5). Note that there is no planned controlled re-entry.

Calculation of area-to-mass ratio after postmission disposal, if the controlled reentry option is not selected:

- Spacecraft Final Mass: 161 kg (worst case mass)
- Cross-sectional Area: 1 m^2 (estimated average area in tumbling)
- Area to mass ratio: 0.006 m^2/kg

Requirement 4.6-1. Disposal for space structures passing through LEO:

A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods: (Requirement 56557)

1. Atmospheric reentry option:
    a. Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch; or
    b. Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission.
2. Storage orbit option: Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO - 500 km.
3. Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission.

Analysis:

VR-1 will follow a concept of operations to ensure a safe disposal within 25 years of the end of the mission.[10] To demonstrate the thruster, the orbit apogee will be initially raised. Following mission completion, the thruster will be used to lower the perigee and reduce orbit lifetime to

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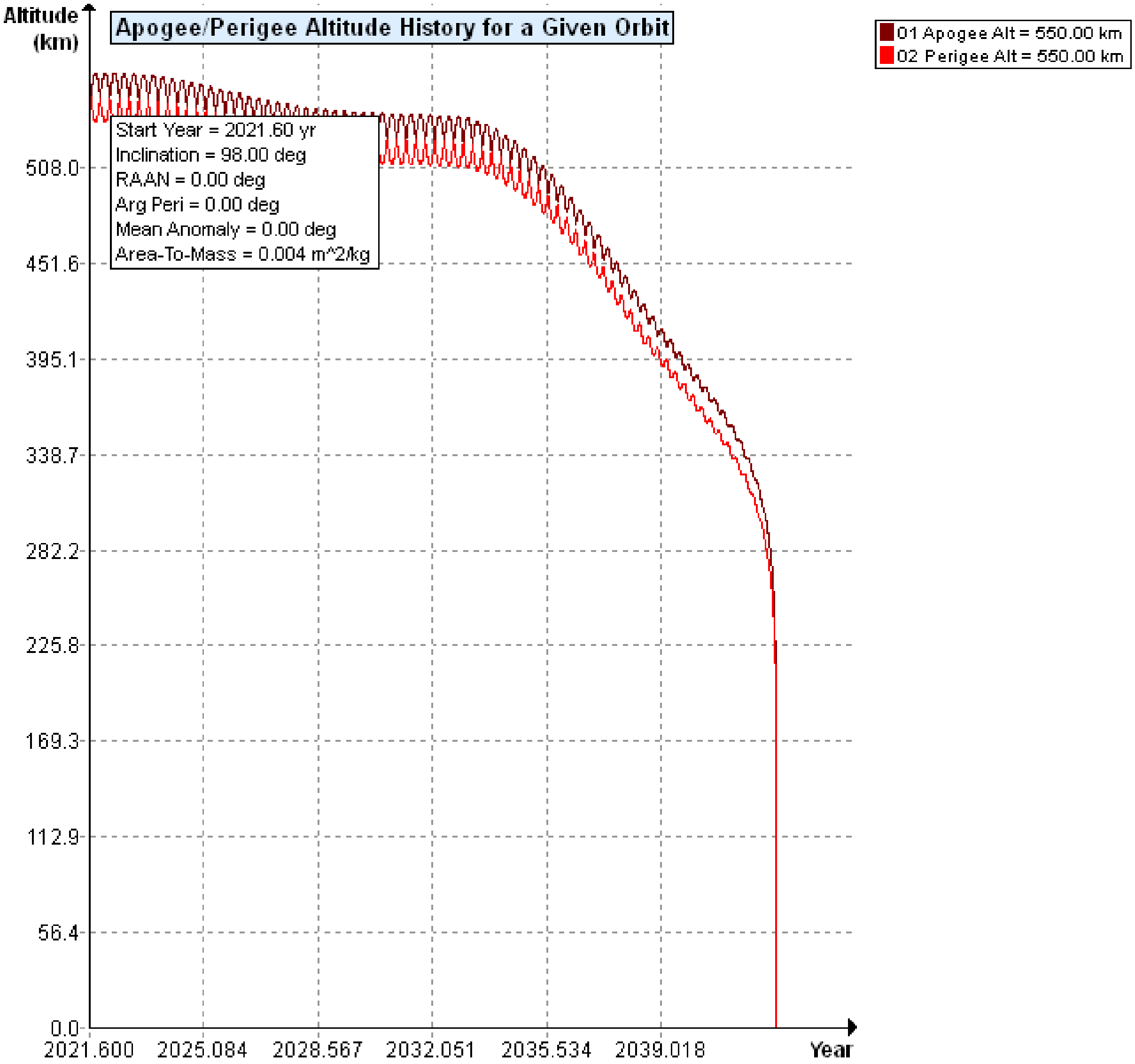
[10] The VR-1 concept of operations results in a calculated worst case maximum de-orbit life of 21 years.

approximately 1 year. In the event of both a propulsion system failure *and* solar array deployment failure on launch, VR-1 is expected to undergo atmospheric re-entry within 21 years. *See* Table 1 *supra*.

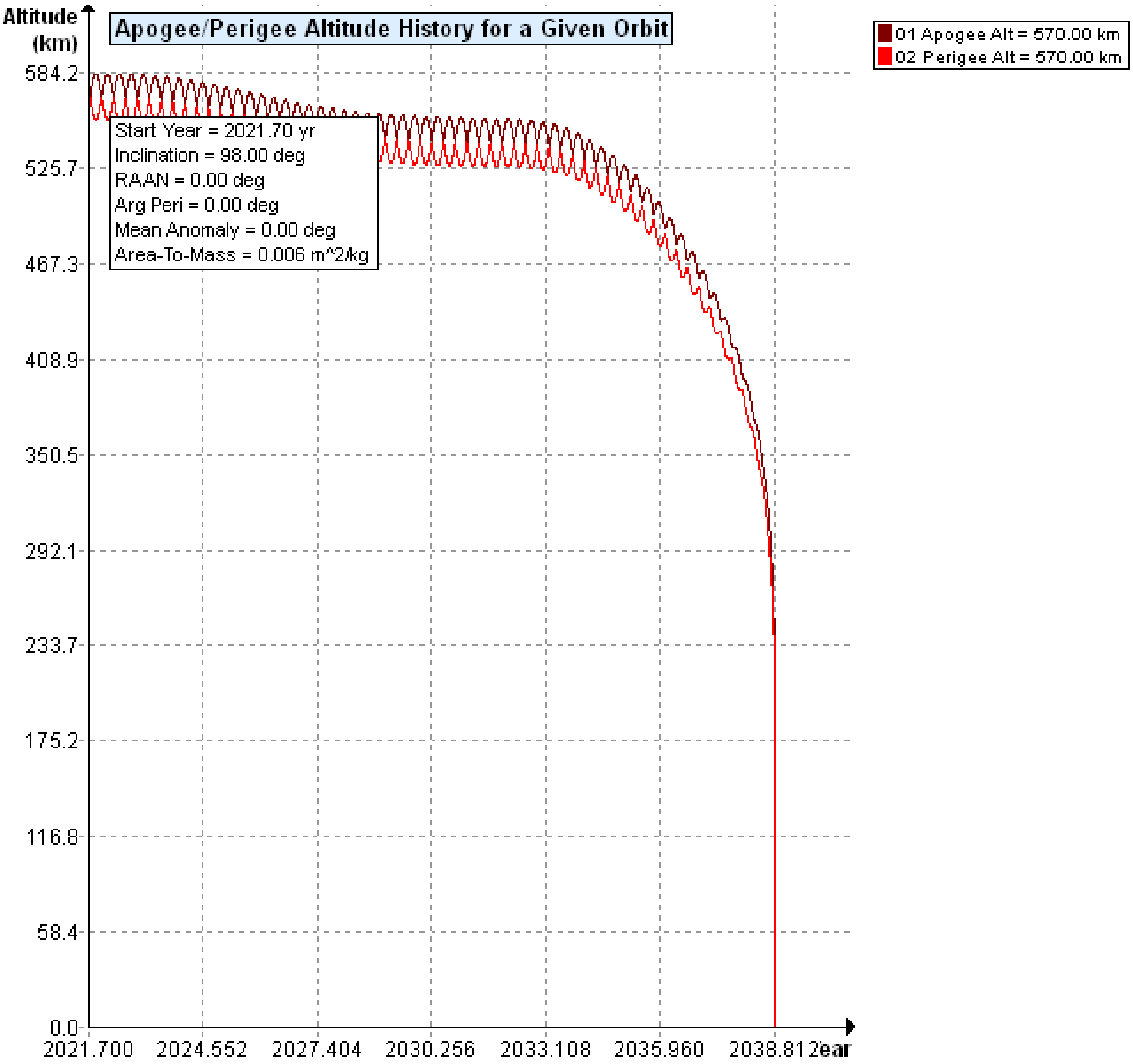
VR-1 Failure at Launch Insertion Orbital Decay (550x550 km)[11]



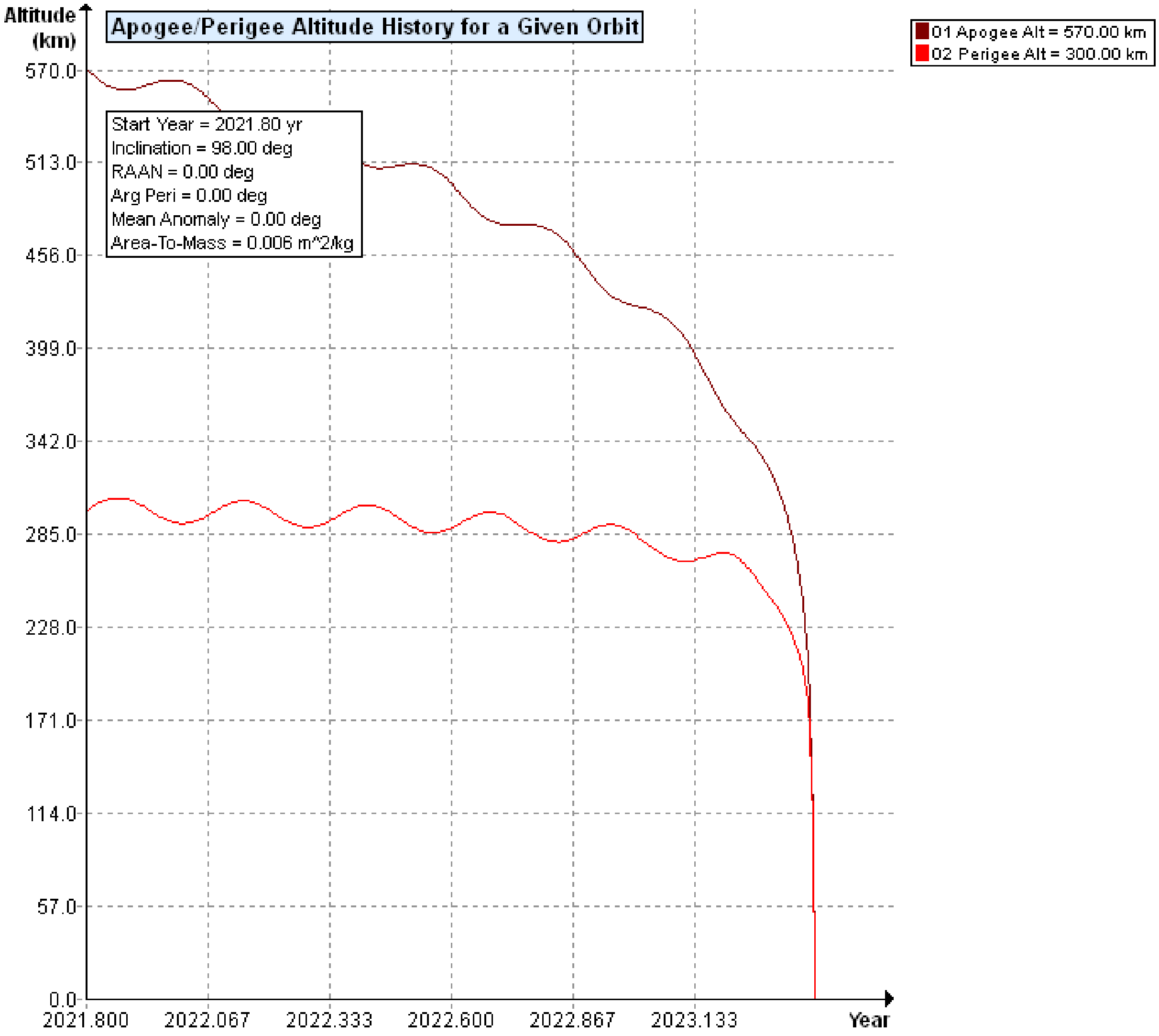
---

[11] VR-1 has an initial Area-to-Mass ratio of 0.004 m^2/kg prior to deployment of its solar arrays, and a final Area-to-Mass ratio of 0.006 m^2/kg post deployment of its solar arrays.

VR-1 Postmission Failure Orbital Decay (570x570 km)



VR-1 Postmission De-Orbit Orbital Decay (300x570 km)



Requirement 4.6-2. Disposal for space structures near GEO.

- Not applicable.

Requirement 4.6-3. Disposal for space structures between LEO and GEO.

- Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

- Not applicable. The satellite will reenter passively without post mission disposal operations within allowable timeframe.

VII. Spacecraft Reentry Hazards

Requirement 4.7-1. Limit the risk of human casualty:

The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules:

1. For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).

Summary Analysis Results: DAS v3.1.0 reports that VR-1 is compliant with the requirement. As shown below, six VR-1 components may survive re-entry. However, in each case the impact energy is less than 15 joules.

Additional representative mass was added to better reflect the worst-case scenario physical mass for re-entry casualty risk. Specific to the deployer masses, as discussed, in lieu of providing constituent component level analyses, we opted to characterize the deployers and payload masses as uniform solid pieces of aluminum – which should result in a conservative assessment. Furthermore, additional piece part-level data was included to reflect the proportionally small (less than 1kg) quantity of the worst-case high-melting temperature fasteners on the VR-1.

Analysis using DAS v3.1.0:

```
02 09 2021; 09:04:56AM        Processing Requirement 4.3-2: Return Status : Passed


=====================

No Project Data Available

=====================



=============== End of Requirement 4.3-2 ===============

02 09 2021; 09:30:49AM        Processing Requirement 4.5-1:        Return Status :  Passed


==============

Run Data

==============
```

```
**INPUT**

        Space Structure Name = Vigoride-1
        Space Structure Type = Payload
        Perigee Altitude = 550.000 (km)
        Apogee Altitude = 550.000 (km)
        Inclination = 98.000 (deg)
        RAAN = 0.000 (deg)
        Argument of Perigee = 0.000 (deg)
        Mean Anomaly = 0.000 (deg)
        Final Area-To-Mass Ratio = 0.0040 (m^2/kg)
        Start Year = 2021.600 (yr)
        Initial Mass = 161.000 (kg)
        Final Mass = 161.000 (kg)
        Duration = 1.000 (yr)
        Station-Kept = False
        Abandoned = True

**OUTPUT**

        Collision Probability = 2.9960E-05
        Returned Message: Normal Processing
        Date Range Message: Normal Date Range
        Status = Pass
```

```
==============

=============== End of Requirement 4.5-1 ===============

02 09 2021; 09:31:30AM        Project Data Saved To File
02 09 2021; 09:31:30AM        Project Data Saved To File
02 09 2021; 09:35:09AM        Requirement 4.5-2:  Compliant

==================================================
Spacecraft = Vigoride-1
Critical Surface = Avionics
==================================================

**INPUT**

        Apogee Altitude = 550.000 (km)
        Perigee Altitude = 550.000 (km)
        Orbital Inclination = 98.000 (deg)
        RAAN = 0.000 (deg)
        Argument of Perigee = 0.000 (deg)
        Mean Anomaly = 0.000 (deg)
        Final Area-To-Mass = 0.0040 (m^2/kg)
        Initial Mass = 161.000 (kg)
        Final Mass = 161.000 (kg)
        Station Kept = No
        Start Year = 2021.600 (yr)
```

```
          Duration = 1.000 (yr)

          Orientation = Random Tumbling

          CS Areal Density = 5.000 (g/cm^2)

          CS Surface Area = 0.5000 (m^2)

          Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))

          CS Pressurized = No

          Outer Wall 1   Density: 10.000 (g/cm^2)  Separation: 30.000 (cm)


**OUTPUT**


          Probability of Penetration = 6.3335E-06 (6.3335E-06)

          Returned Error Message: Normal Processing

          Date Range Error Message: Normal Date Range


=============== End of Requirement 4.5-2 ===============


02 09 2021; 09:35:31AM        Processing Requirement 4.6  Return Status :  Passed


==============

Project Data

==============


**INPUT**


          Space Structure Name = Vigoride-1

          Space Structure Type = Payload
```

```
        Perigee Altitude = 550.000000 (km)
        Apogee Altitude = 550.000000 (km)
        Inclination = 98.000000 (deg)
        RAAN = 0.000000 (deg)
        Argument of Perigee = 0.000000 (deg)
        Mean Anomaly = 0.000000 (deg)
        Area-To-Mass Ratio = 0.004000 (m^2/kg)
        Start Year = 2021.600000 (yr)
        Initial Mass = 161.000000 (kg)
        Final Mass = 161.000000 (kg)
        Duration = 1.000000 (yr)
        Station Kept = False
        Abandoned = True
        PMD Perigee Altitude = 535.229970 (km)
        PMD Apogee Altitude = 563.466451 (km)
        PMD Inclination = 98.041784 (deg)
        PMD RAAN = 18.865591 (deg)
        PMD Argument of Perigee = 103.919919 (deg)
        PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

        Suggested Perigee Altitude = 535.229970 (km)
        Suggested Apogee Altitude = 563.466451 (km)
        Returned Error Message = Passes LEO reentry orbit criteria.
```

```
          Released Year = 2042 (yr)

          Requirement = 61

          Compliance Status = Pass


==============


=============== End of Requirement 4.6 ===============

02 09 2021; 09:36:09AM          *********Processing Requirement 4.7-1

          Return Status :  Passed


***********INPUT****

 Item Number = 1


name = Vigoride-1

quantity = 1

parent = 0

materialID = 8

type = Box

Aero Mass = 161.000000

Thermal Mass = 161.000000

Diameter/Width = 0.620000

Length = 0.690000

Height = 0.620000


name = Structure
```

quantity = 2

parent = 1

materialID = 8

type = Box

Aero Mass = 7.700000

Thermal Mass = 7.700000

Diameter/Width = 0.250000

Length = 0.600000

Height = 0.250000

name = Diaphragm Tank Middle

quantity = 2

parent = 1

materialID = 27

type = Cylinder

Aero Mass = 0.250000

Thermal Mass = 0.250000

Diameter/Width = 0.150000

Length = 0.300000

name = Diaphragm Tank End 1

quantity = 2

parent = 1

materialID = 27

type = Sphere

Aero Mass = 0.100000

Thermal Mass = 0.100000

Diameter/Width = 0.150000

name = Diaphragm Tank End 2

quantity = 2

parent = 1

materialID = 27

type = Sphere

Aero Mass = 0.100000

Thermal Mass = 0.100000

Diameter/Width = 0.150000

name = Diaphragm Tank Liner

quantity = 2

parent = 1

materialID = 8

type = Cylinder

Aero Mass = 1.200000

Thermal Mass = 1.200000

Diameter/Width = 0.200000

Length = 0.200000

name = Prototype Tank

quantity = 2

parent = 1

materialID = 8

type = Box

Aero Mass = 1.800000

Thermal Mass = 1.800000

Diameter/Width = 0.150000

Length = 0.200000

Height = 0.150000

name = Chamber

quantity = 1

parent = 1

materialID = 54

type = Cylinder

Aero Mass = 0.030000

Thermal Mass = 0.030000

Diameter/Width = 0.030000

Length = 0.032000

name = Window

quantity = 1

parent = 1

materialID = 1

type = Cylinder

Aero Mass = 0.008000

Thermal Mass = 0.008000

Diameter/Width = 0.030000

Length = 0.015000

name = Reaction Wheels
quantity = 3
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.080000
Length = 0.060000

name = Reaction Control Thruster
quantity = 4
parent = 1
materialID = 19
type = Box
Aero Mass = 0.085000
Thermal Mass = 0.085000
Diameter/Width = 0.050000
Length = 0.050000
Height = 0.040000

name = Shields
quantity = 4
parent = 1
materialID = 66

type = Flat Plate

Aero Mass = 0.025000

Thermal Mass = 0.025000

Diameter/Width = 0.060000

Length = 0.060000

name = 12U CubeSat Deployer Dummy

quantity = 1

parent = 1

materialID = 8

type = Box

Aero Mass = 26.400000

Thermal Mass = 26.400000

Diameter/Width = 0.400000

Length = 0.600000

Height = 0.400000

name = Radiator Plate

quantity = 1

parent = 1

materialID = 8

type = Box

Aero Mass = 3.500000

Thermal Mass = 3.500000

Diameter/Width = 0.600000

Length = 0.600000

Height = 0.020000

name = Solar Array

quantity = 2

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 2.600000

Thermal Mass = 2.600000

Diameter/Width = 0.600000

Length = 1.400000

name = 12U Cubesat Deployer

quantity = 1

parent = 1

materialID = 8

type = Box

Aero Mass = 26.500000

Thermal Mass = 26.500000

Diameter/Width = 0.400000

Length = 0.600000

Height = 0.400000

name = Payload Interface Adapter

quantity = 2

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 2.000000

Thermal Mass = 2.000000

Diameter/Width = 0.200000

Length = 0.300000

name = Payload Interface Plate

quantity = 1

parent = 1

materialID = 8

type = Box

Aero Mass = 28.000000

Thermal Mass = 28.000000

Diameter/Width = 0.600000

Length = 0.600000

Height = 0.300000

name = Structural Fasteners

quantity = 100

parent = 1

materialID = 57

type = Cylinder

Aero Mass = 0.010000

Thermal Mass = 0.010000

Diameter/Width = 0.010000

```
Length = 0.020000


**************OUTPUT****

Item Number = 1


name = Vigoride-1

Demise Altitude = 77.995506

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


*************************************

name = Structure

Demise Altitude = 72.456932

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


*************************************

name = Diaphragm Tank Middle

Demise Altitude = 0.000000

Debris Casualty Area = 1.319117

Impact Kinetic Energy = 13.947386


*************************************

name = Diaphragm Tank End 1

Demise Altitude = 0.000000

Debris Casualty Area = 1.074385
```

```
Impact Kinetic Energy = 10.209132


**************************************

name = Diaphragm Tank End 2

Demise Altitude = 0.000000

Debris Casualty Area = 1.074385

Impact Kinetic Energy = 10.209132


**************************************

name = Diaphragm Tank Liner

Demise Altitude = 75.059624

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


**************************************

name = Prototype Tank

Demise Altitude = 73.715111

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


**************************************

name = Chamber

Demise Altitude = 75.039986

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000
```

```
**************************************

name = Window

Demise Altitude = 0.000000

Debris Casualty Area = 0.385906

Impact Kinetic Energy = 1.099499


**************************************

name = Reaction Wheels

Demise Altitude = 0.000000

Debris Casualty Area = 1.343816

Impact Kinetic Energy = 11.485331


**************************************

name = Reaction Control Thruster

Demise Altitude = 76.712646

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


**************************************

name = Shields

Demise Altitude = 0.000000

Debris Casualty Area = 1.742400

Impact Kinetic Energy = 2.833590


**************************************

name = 12U CubeSat Deployer Dummy
```

```
Demise Altitude = 63.761108

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************

name = Radiator Plate

Demise Altitude = 73.131889

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************

name = Solar Array

Demise Altitude = 76.252495

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************

name = 12U Cubesat Deployer

Demise Altitude = 63.710724

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************

name = Payload Interface Adapter

Demise Altitude = 71.184097

Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000


************************************

name = Payload Interface Plate

Demise Altitude = 51.403866

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************

name = Structural Fasteners

Demise Altitude = 75.827385

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000


************************************


=============== End of Requirement 4.7-1 ===============
```

VIII. Tether Missions

Not applicable.

Annex A - VR-1 Worst-Case Large Object Collision Risk

```
03 24 2021; 16:37:45PM Opened Project C:\Users\sam.avery\Momentus\Engineering -
Documents\Guilds\Systems Guild\Simulation and Analysis\Debris Assessment
Software\NASA\DAS3.1.0\project - V1\
03 24 2021; 16:38:23PM Mission Editor Changes Applied
03 24 2021; 16:38:23PM Project Data Saved To File
03 24 2021; 16:38:40PM Processing Requirement 4.3-1:	Return Status :  Not Run
=====================
No Project Data Available
=====================
=============== End of Requirement 4.3-1 ===============
03 24 2021; 16:38:43PM Processing Requirement 4.3-2: Return Status : Passed
=====================
No Project Data Available
=====================
=============== End of Requirement 4.3-2 ===============
03 24 2021; 17:58:32PM Processing Requirement 4.5-1:	Return Status :  Passed
==============
Run Data
==============


**INPUT**
	Space Structure Name = Vigoride-1
	Space Structure Type = Payload
	Perigee Altitude = 570.000 (km)
	Apogee Altitude = 570.000 (km)
	Inclination = 98.000 (deg)
	RAAN = 0.000 (deg)
	Argument of Perigee = 0.000 (deg)
	Mean Anomaly = 0.000 (deg)
	Final Area-To-Mass Ratio = 0.0040 (m^2/kg)
	Start Year = 2021.600 (yr)
	Initial Mass = 161.000 (kg)
	Final Mass = 161.000 (kg)
	Duration = 1.000 (yr)
	Station-Kept = False
	Abandoned = True
**OUTPUT**
	Collision Probability = 4.8995E-05
	Returned Message: Normal Processing
	Date Range Message: Normal Date Range
	Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
03 24 2021; 17:58:36PM Project Data Saved To File
03 24 2021; 18:06:14PM Requirement 4.5-2:  Compliant
==================================================
Spacecraft = Vigoride-1
Critical Surface = Avionics
==================================================
**INPUT**
```

```
        Apogee Altitude = 570.000 (km)
        Perigee Altitude = 570.000 (km)
        Orbital Inclination = 98.000 (deg)
        RAAN = 0.000 (deg)
        Argument of Perigee = 0.000 (deg)
        Mean Anomaly = 0.000 (deg)
        Final Area-To-Mass = 0.0040 (m^2/kg)
        Initial Mass = 161.000 (kg)
        Final Mass = 161.000 (kg)
        Station Kept = No
        Start Year = 2021.600 (yr)
        Duration = 1.000 (yr)
        Orientation = Random Tumbling
        CS Areal Density = 5.000 (g/cm^2)
        CS Surface Area = 0.5000 (m^2)
        Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
        CS Pressurized = No
        Outer Wall 1   Density: 10.000 (g/cm^2)  Separation: 30.000 (cm)
**OUTPUT**
        Probability of Penetration = 7.3801E-06 (7.3801E-06)
        Returned Error Message: Normal Processing
        Date Range Error Message: Normal Date Range
=============== End of Requirement 4.5-2 ===============
```

EXHIBIT 4

Antenna Gain Plots

Vigoride-1 Spacecraft NGSO Antenna Gain Plots

V3
03/24/2021

Momentus Inc.

3050 Kenneth Street

Santa Clara, CA 95054

+1 (650) 564-7820

Revision History

1	Initial Release	All	Sam Avery	08/07/20
2	Updated contour labels	All	Sam Avery	08/08/20
3	Re-issued	All	Sam Avery	03/24/21

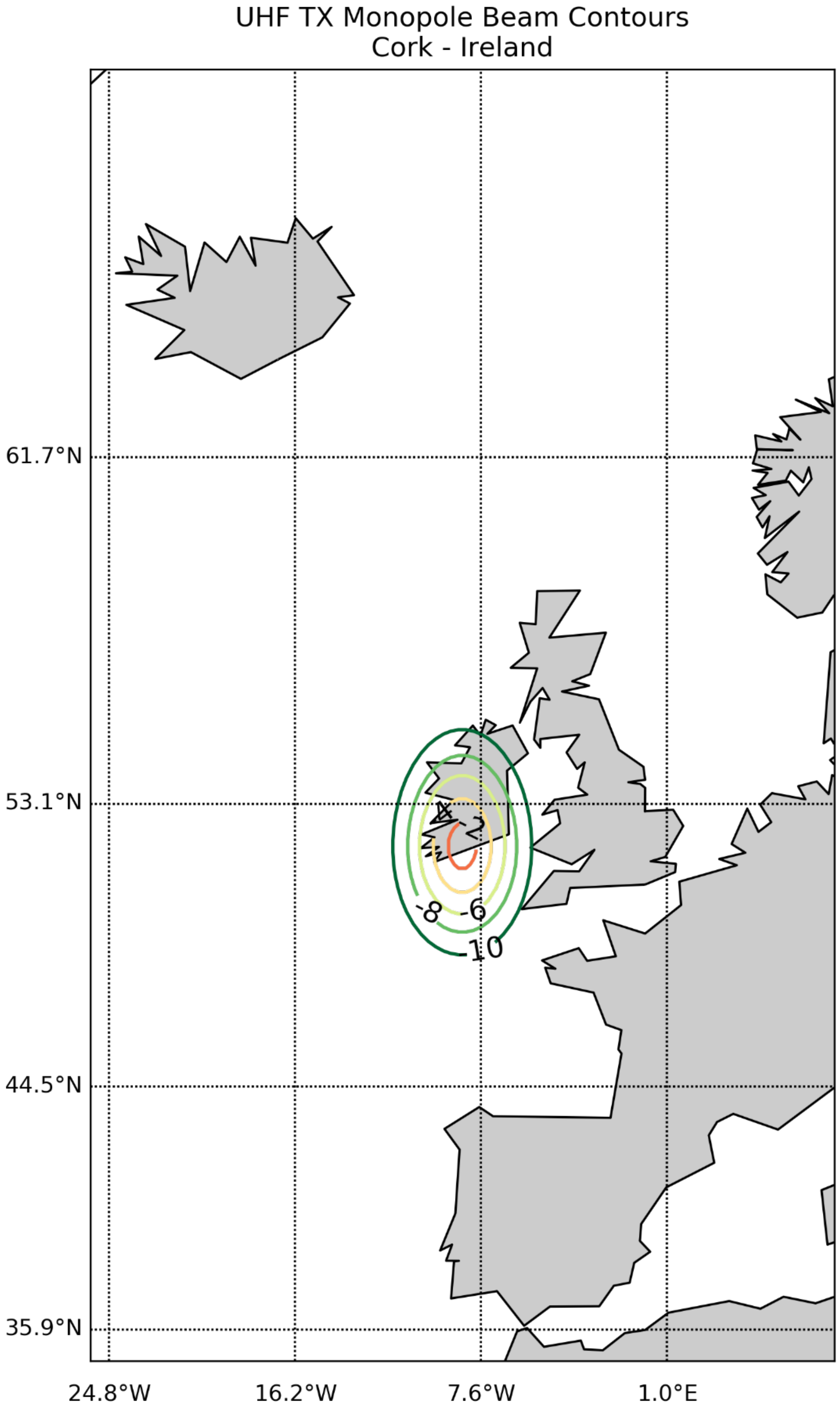
Table of Contents

I. Introduction

All contour plots show a map of the Earth out to the horizon for each ground station and satellite antenna pair. The plot labels indicate antenna gain contours in 2 dB steps down to 10 dB below the peak gain. For instance, a contour label of “-2” indicates 2 dB below the maximum gain for that antenna.

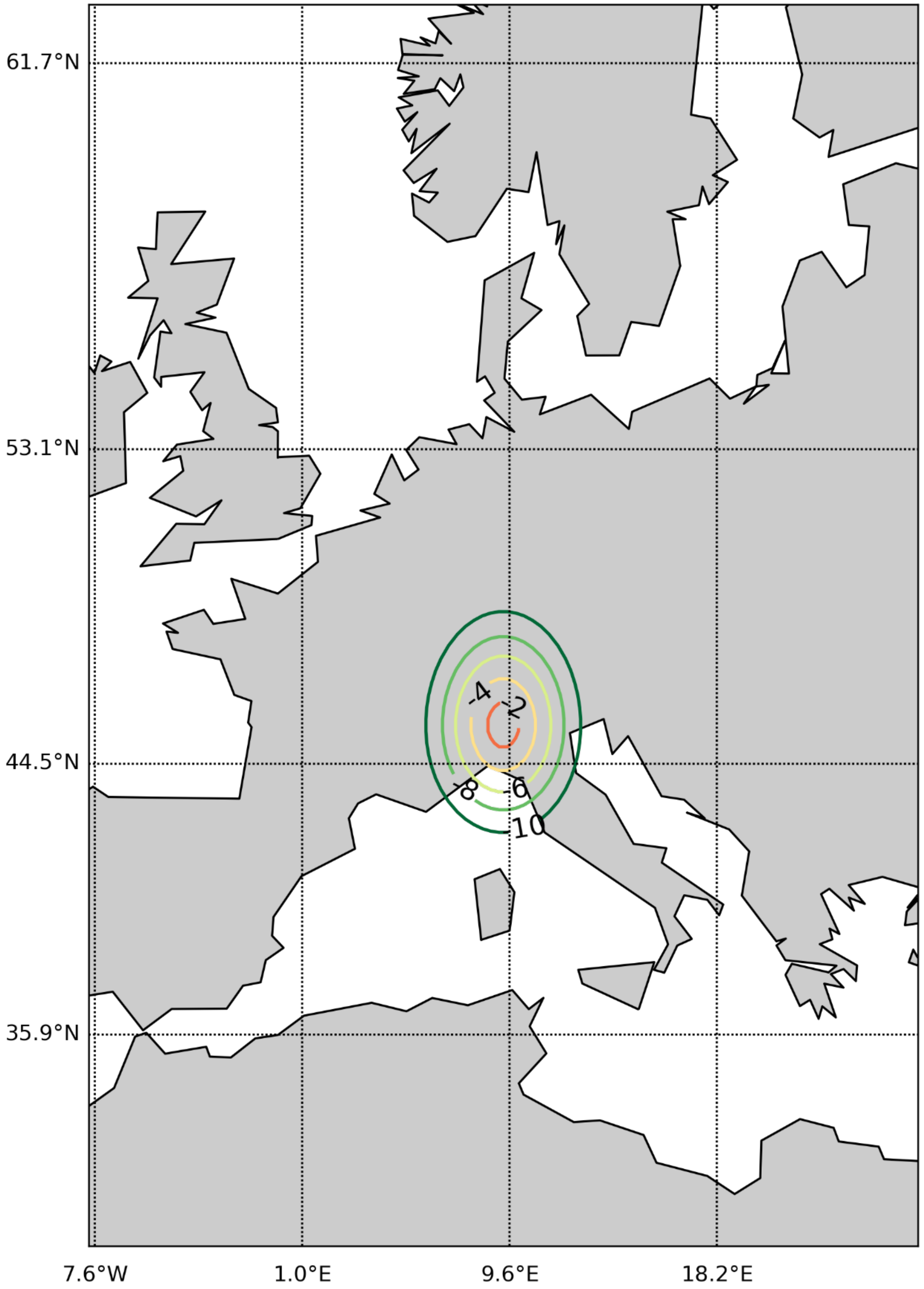
Note that for the Uplink (S-band receive) gain contour plots, the point of 10 dB below peak gain is beyond the horizon and is not shown in the plots.

II. Downlink Gain Contour Plots

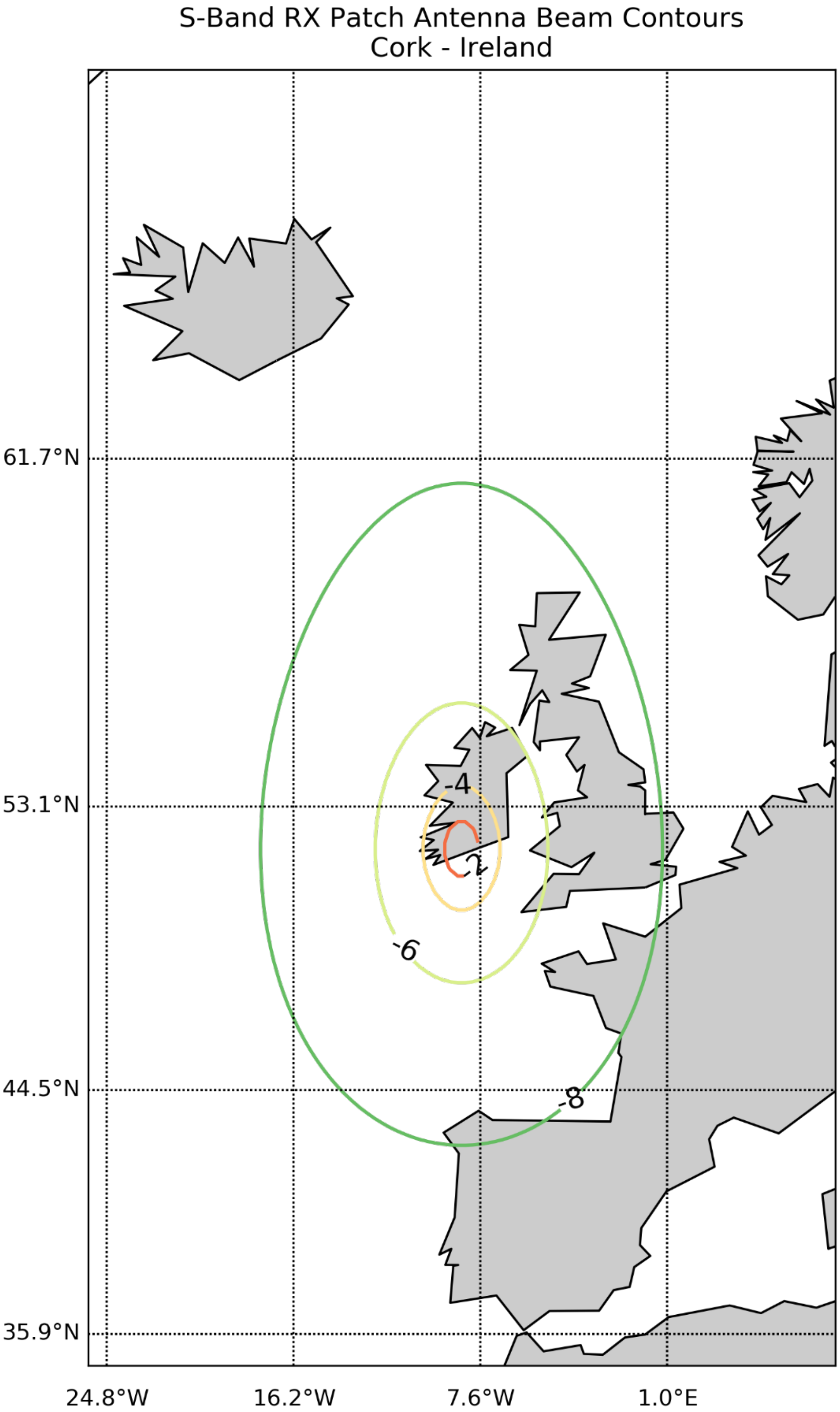


UHF TX Monopole Beam Contours
Cork - Ireland

UHF TX Monopole Beam Contours
Vimercate - Italy



III. Uplink Gain Contour Plots



S-Band RX Patch Antenna Beam Contours
Vimercate - Italy