

Lumen-1
Application for Part-5 Experimental
License
Narrative

Ezra Feilden

Ezra Feilden, CTO
Lumen Orbit, Inc.

I. Mission Summary

By this application, Lumen Orbit, Inc. (“Lumen”) seeks Federal Communications Commission (“FCC”) authorization to conduct a demonstration satellite mission in support of the company’s long-term goal of building an in-orbit edge computing satellite network that will support in-orbit processing earth observation data from Earth imaging systems. The development of such a service is widely in the public interest as it ultimately facilitates more efficient use of spectrum via reduced terrestrial downlink through in-orbit edge processing.

The Lumen-1 mission is Lumen’s first satellite mission and will demonstrate technologies required to build an in-orbit edge computing node for our orbital data center concept. The hardware required for this capability requires a low-radiation environment. To meet this requirement Lumen-1 will lower its apogee and perigee to 325 km using an electric propulsion system where ionizing radiation is minimal and payload testing may commence. Following these demonstrations, Lumen-1 will use the electric propulsion system to lower the orbit of the spacecraft to a disposal orbit.

II. Mission Phases

The Lumen-1 experimental spacecraft is expected to be launched on a SpaceX Falcon 9 Bandwagon-4 mission in H2 2025 and inserted into a 45 +/- 1.1 degree inclination orbit with a perigee and apogee of 515 km +/- 25 km. The Lumen-1 mission is comprised of the following phases. Throughout each phase, Lumen-1 will utilize its S-band uplink, UHF downlink, and L-band intersatellite link (“ISL”).

1. After release from the launch vehicle and post-launch bus commissioning, Lumen-1 will maneuver from its insertion orbit to its target operational 325 km circular orbit using its propulsion system. A more detailed discussion of the transfer orbit path is discussed in the ODAR. This segment is expected to take roughly 6 months.
2. When Lumen-1 reaches its operational orbit, it will commence testing of the primary payload - an onboard computer. This segment is expected to take approximately 2 months.
3. Following completion of Lumen-1’s primary mission, the spacecraft will monitor the mission’s secondary payload - a commercial off-the-shelf software defined radio system (“SDR”). The effect of the space environment and radiation will be evaluated with periodic health checks in preparation for the Lumen-2 mission. This SDR has the capability of receiving X-band signals from other satellites. However, this capability is not intended to be tested with Lumen-1. If in the future the plans change, Lumen Orbit will seek the necessary approval from the FCC.
4. Following completion of the mission objectives Lumen-1 will passively deorbit and demise.

The attached ODAR demonstrates that Lumen-1 meets the FCC’s orbital debris requirements.

The expected mission lifetime is 11 months.

III. Satellite Bus Subsystems

The Lumen-1 spacecraft is built on the reliable Astro Digital US Corvus Micro platform. This platform features primary satellite subsystems with extensive on-orbit heritage, having been previously approved and successfully utilized across multiple satellites and systems:

1. Guidance, Navigation and Control Subsystem
Attitude determination and control system includes one star tracker, three reaction wheels, three torque rods, a 3-axis magnetometer, a 3-axis inertial measurement unit, a global positioning system (“GPS”) receiver, and coarse sun sensors.
2. Command and Data Handling Subsystem
The Flight Computer (“FC”) receives instructions from the ground station(s) via the dedicated S-Band and UHF TT&C Subsystem or the L-band ISL. The FC issues commands to all other subsystems and payloads for operation of the satellite. Additionally, the FC collects telemetry

from all subsystems and forwards that information to the ground station through the TT&C Communication Subsystem or L-band ISL payload.

3. Electrical Power Subsystem

The bus’s electrical power system will collect and store power from its fixed and deployable solar panels, and deliver power to support the Lumen-1 payloads and other bus subsystems. The solar arrays provide a peak power collection of $\geq 150W$ to provide a fully margined OAP to the payload for all mission segments.

4. Thermal Control Subsystem

The Lumen-1 spacecraft will utilize thermal control coatings, thermal sensors and heaters to ensure spacecraft subsystem temperatures are maintained with operational and storage ranges depending on mission Concept of Operations (“CONOPS”).

5. Structure Subsystem

The structure for the spacecraft is custom made for this mission and provides structural integrity and radiation shielding to the internal modules.

6. Propulsion Subsystem

The propulsion system on the satellite is a state-of-the-art ThrustMe NPT30-I2 system. It has no moving parts and uses solid iodine as the propellant. There are no liquids or pressurized vessels.

IV. Communications Systems

The Lumen-1 spacecraft has four independent radio subsystems:

1. a TT&C radio receiving S-band frequencies from ground stations and associated RX antenna
2. a TT&C and payload data radio transmitting UHF frequencies to ground stations and associated TX antenna
3. a commercial-off-the-shelf software defined radio (“SDR”) with an X-band RX antenna. As discussed above, the antenna receive capability is not intended to be tested during the Lumen-1 mission. If in the future the plans change, Lumen will seek the necessary approval from the FCC.
4. a Cryptosat cEDGE L-band intersatellite radio terminal and associated TX/RX antennas communicating with Iridium satellites.

Table 1. Specification of each RF beam transmitted and received by Lumen-1.

Beam Name	Direction	Lower Freq (MHz)	Upper Freq (MHz)	Channel Bandwidth (kHz)	EIRP (dBW)
UHF TT&C Tx	Space-to-earth	400.48	400.52	40	5.5
S-Band TT&C Rx	Earth-to-space	2025.0	2110.0	85000	N/A
L-Band ISL Rx	Space-to-space	1618.725	1626.5	35 333	N/A
L-Band ISL Tx	Space-to-space	1618.725	1626.5	35 333	20.9

The Lumen-1 mission does not comply with Section 5.115 of the Commission’s Rules which requires the provision of a station identification. The mission does not transmit the call sign at the end of the transmission in either clear voice or Morse code, as the satellite does not have the ability to do so. Also, the satellite maximizes the full duration of the downlink communication time for mission critical space operations telemetry. Lumen Orbit acknowledges the intent of the rule for station identification as a means of allowing others to trace unwanted interference, and assumes that the frequency coordination process will accomplish the same purpose in this regard. As such, Lumen Orbit respectfully requests a waiver for Section 5.115 of the Commission’s Rules.

Communications Subsystems

The Lumen-1 spacecraft bus utilizes a dedicated radio to provide space-to-Earth and Earth-to-space communications for TT&C and payload data, detailed below. Radio communication with ground stations will initiate at elevation angles above 10 degrees. A list of the relevant ground stations is attached.

400.48-400.52 MHz (space-to-Earth)

The 400.15-401 MHz (space-to-Earth) band is allocated internationally and in the U.S for federal and non-federal mobile-satellite and space research use on a primary basis as well as for federal and non-federal space operation use on a secondary basis. Lumen-1's use of the spectrum for space operations is therefore consistent with the U.S. and International Table of Frequency Allocations. Lumen will complete coordination with Federal operators for use of these frequencies as required.

Lumen is aware that the FCC established an October 15, 2019, cut-off deadline for requests to operate in the 400.15-401 MHz band for the provision of Mobile-Satellite Service. Lumen proposes to use this band for space operations on a secondary basis, consistent with the U.S. Table of Frequency Allocations, and its 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 not be treated as inconsistent with the 400.15-401 MHz processing round.

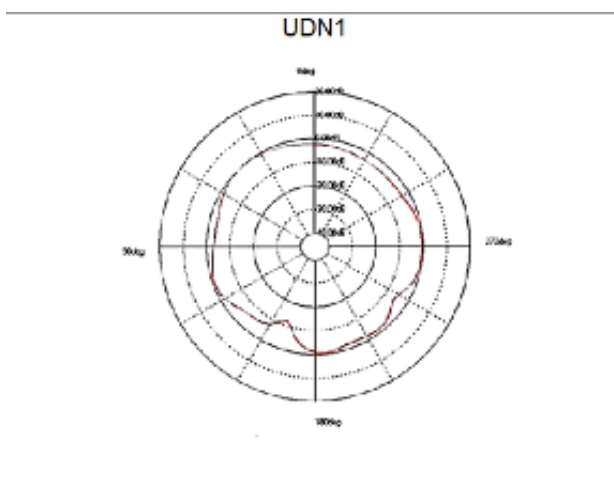


Figure 1. UHF Space Station Antenna Pattern

2025-2110 MHz (Earth-to-space)

The 2025-2110 MHz (Earth-to-space) band is allocated internationally for space operations, EESS, and space research. In the United States, non-Federal use is limited to EESS and space research, subject to conditions as may be applied on a case-by-case basis and the limitation that any use may not cause harmful interference to authorized Federal and non-Federal operations. Lumen-1 will only communicate with non-U.S. ground stations, and accordingly, the use of the S-band uplink for space operations is consistent with the International Table of Frequency Allocations.

Additionally, because Lumen-1 is a demonstration mission to test equipment and capabilities and future Lumen missions will support EESS missions, Lumen-1's use of the spectrum could also be treated as space research and/or EESS consistent with the U.S. Table of Frequency Allocations.

Use of this band will be coordinated ensuring that operations will not cause harmful interference. Sharing of spectrum will be possible because Lumen-1 and other satellites using these frequencies transmit and receive only in short periods of time while visible to a receiving/transmitting earth station main beam. For harmful interference to occur, satellites belonging to different systems would have to be visible to the earth station and transmitting or receiving using the same frequencies at the exact same time. In such an unlikely event, the resulting inline interference could be avoided by coordinating the satellite transmissions so that they do not occur simultaneously. Accordingly, there is no mutual exclusivity between Lumen-1 and other non-geostationary satellite ("NGSO") systems using

the same frequency band. Lumen will also comply with technical requirements in Part 2 of the Commission’s rules and applicable ITU rules and complete coordination with Federal operators as required.

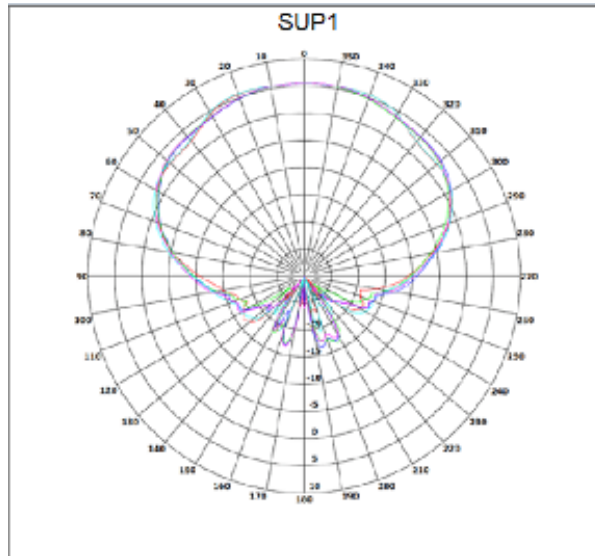


Figure 2. S-band Space Station Antenna Pattern

1618.725-1626.5 MHz Intersatellite Link (Space-to-Space)

Lumen-1 includes one cEDGE module which provides low-bandwidth, duplex, on-demand communications via Iridium’s NGSO system, as a customer of Iridium. The terminal will transmit and receive in the 1618.725-1626.5 MHz frequency band, which is allocated for the Mobile-Satellite Service. Lumen Orbit requests to use the frequencies in order to communicate through the Iridium system. Lumen Orbit requests a waiver of the U.S. Table of Frequency Allocations and any other applicable FCC rule to communicate with Iridium satellites. Lumen Orbit expects Iridium to file a separate companion application for authority to conduct such communications. The Commission may waive any of its rules if there is “good cause” to do so. 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. 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. Lumen Orbit submits that good cause exists to waive the U.S. Table of Frequency Allocations. Transmissions will occur only on frequencies that Iridium assigns to the terminals onboard the Lumen-1 spacecraft. Lumen Orbit understands that transmissions are on a non-conforming basis. For the above reasons, grant of the waiver is justified.

The c-EDGE unit consists of five antennas with the following transmission characteristics:

Antenna Name	An0	An1	An2	An3	An4
Directional antenna (other than radar)	Yes	Yes	Yes	Yes	Yes
Width of beam in degrees at the half-power point	See pattern 1	See pattern 2	See pattern 2	See pattern 2	See pattern 2
Orientation	Tumble	Tumble	Tumble	Tumble	Tumble

Can the station transmit its call sign at the end of each transmission	No	No	No	No	No
Frequency Range (MHz)	1618.725 MHz to 1626.5MHz	1618.725 MHz to 1626.5MHz	1618.725 MHz to 1626.5MHz	1618.725 MHz to 1626.5MHz	1618.725 MHz to 1626.5MHz
Output Power (W)	10 Watt / 10dBW	1.6 Watt / 2dBW	1.6 Watt / 2dBW	1.6 Watt / 2dBW	1.6 Watt / 2dBW
ERP (W)	9.7 W	2.72 W	2.72 W	2.72 W	2.72 W
Emission Designator	333K3Q7 W	35K0G1W	35K0G1W	35K0G1W	35K0G1W
Modulating Signal	QPSK, DQPSK	DQPSK	DQPSK	DQPSK	DQPSK

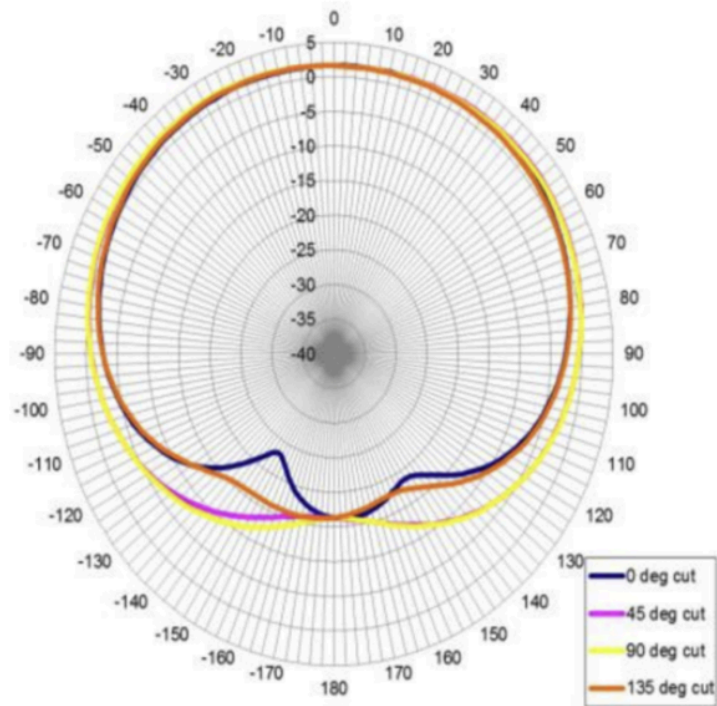


Figure 3. Antenna Pattern 1

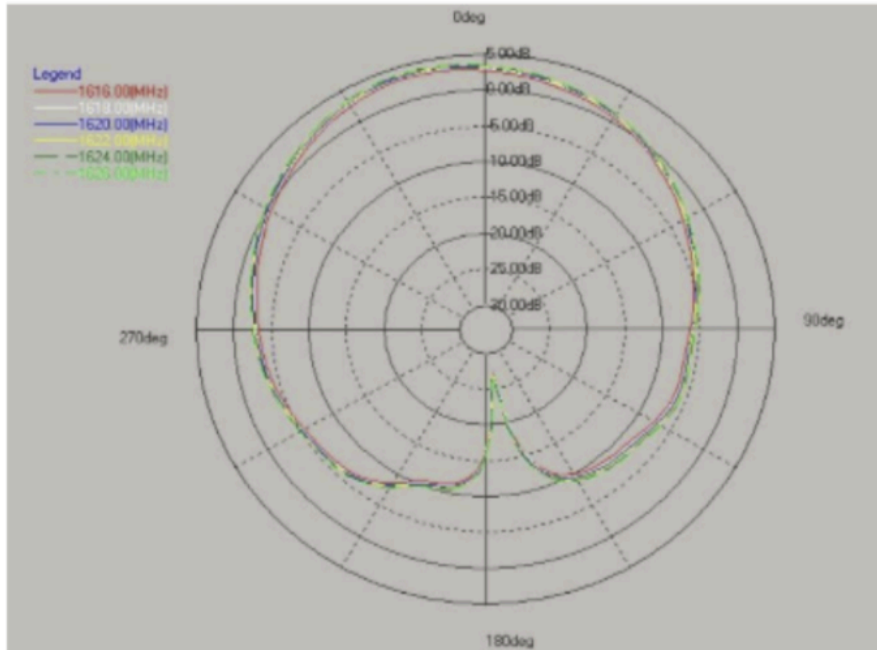


Figure 4. Antenna Pattern 2

Antenna beam orientation compared to cEDGE unit

An0 is shown in purple (hemisphere, antenna pattern 1)

An1 through An4 are shown in blue (conical, antenna pattern 2)

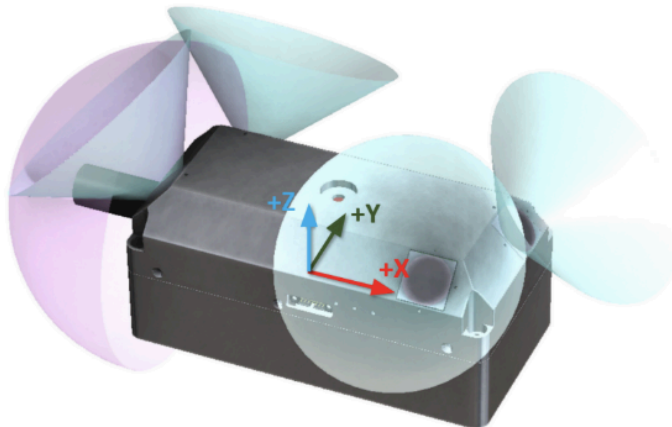


Figure 5. Cryptosat antenna configuration.

Interference considerations in the 1618.725-1626.5 MHz band

Lumen-1 has been integrated with one cEDGE module supplied by Aptos Inc. This single module incorporates Iridium 4x9663 and 1x9770 transceiver modems enabling communication with the Iridium satellite constellation. The transmissions consist of satellite commands, telemetry, and payload data. The space-to-space communications between the systems otherwise conform to Iridium's authorized operating parameters and should be authorized consistent with Commission precedent. Out of an abundance of caution, Lumen requests a waiver of Section 2.106 of the Commission's rules to allow communications between Lumen-1 and the Iridium system in the 1618.725-1626.5 MHz band. Transmissions between the spacecraft will only occur on frequencies assigned by Iridium to the spaceborne Iridium modems, ensuring there is no harmful interference.

Ground Stations

A list of the planned ground stations for S-band and UHF band communications is provided below:

Name	Location	Uplink Frequencies	Downlink Frequencies
Leaf Space	Lomazzo, Italy		UHF
Leaf Space	Vimercate, Italy	S-Band	UHF
Leaf Space	Santa Maria, Portugal	S-Band	UHF
RBC	Pretoria, South Africa	S-Band	UHF
Leaf Space	Kaspichan, Bulgaria	S-Band	UHF

ITU Compliance

Lumen has prepared the ITU Advance Publication Information submission for its proposed system and is contemporaneously providing this information to the Commission under separate cover. Contemporaneously with this application, Lumen is submitting a signed ITU cost-recovery letter.