ATTACHMENT A

Technical Appendix

A.1 SCOPE AND PURPOSE

This Technical Appendix provides the Federal Communications Commission ("Commission") with the information not captured in the associated Schedule S regarding the technical characteristics of Intuitive Machines, LLC's ("Intuitive Machines") NOVA-C Lunar Lander (the "NOVA-C") and payloads comprising Intuitive Machines' upcoming commercial mission to the Moon (the "IM-3 Mission"). The NOVA-C has been developed by Intuitive Machines for the NASA Commercial Lander Payload Services ("CLPS") program and will be carrying multiple payloads to the lunar surface. The IM-3 Mission is a nominal 38-day lunar mission, with up to 14 days spent performing payload data collection and transmission on the surface of the Moon.

The NOVA-C is currently planned to launch in Q1 of 2026, therefore Intuitive Machines respectfully requests that the Commission consider and authorize the proposed operations as soon as reasonably practicable. Intuitive Machines will update the Commission with the final launch date once the launch schedule is finalized.

A.2 GENERAL DESCRIPTION

Intuitive Machines seeks authority to operate the NOVA-C under the Commission's small spacecraft rules.[1]

The IM-3 Mission will operate in multiple phases: (i) Launch Phase; (ii) Transit Phase; (iii) Lunar Orbit Phase; and (iv) Lunar Surface Phase. After launch and launch vehicle separation, Intuitive Machines' control facility in Houston will establish communications with the NOVA-C as quickly as possible during the early Transit Phase to begin tracking the spacecraft and compute the first Trajectory Correction (TCM) burn. This Transit Phase lasts for approximately 4 to 8 days to reach lunar orbit depending on launch day.

The NOVA-C will generally use its two Thales Alenia ("Thales") transceivers with hemispherical antennas ("Hemi antennas") during the Transit Phase. The two transceivers have 8 W of RF transmit power and four (4) low-gain antennas (5.6 dBi) for redundancy. The Thales transceivers will receive uplink (Earth-to-space) signals using independent antennas, and one primary transceiver will be active for transmit.

During the Transit Phase, two-tone ranging and doppler data are required. The NOVA-C will also intermittently utilize one of two Quasonix transmitters, each with up to 25W RF transmit power, in conjunction with a high-gain antenna (15.6 dBi) during the Transit Phase. The Thales transceivers and Quasonix transmitters will be utilized during the 1-3 day Lunar Orbit Phase in preparation for autonomous descent and landing on the lunar surface. During each orbit of the Moon, NOVA Control will lose contact with the NOVA-C when it goes behind the Moon and the

[1] *See In the Matter of Streamlining Licensing Procedures for Small Satellites*, IB Docket No. 18-86, Report and Order, 34 FCC Rcd 13077, (2019) ("*Smallsat Order*").

lunar tracking, telemetry, and command network ("LTN") will need to re-acquire contact when in line-of-sight.

During the Lunar Surface Phase, the Quasonix transmitters will be used to transmit data to Earth. The Thales transceivers will continue to be used for telemetry, tracking, and control ("TT&C") and spacecraft system monitoring. The Thales transceivers will have transmit and receive frequencies that are different from the Quasonix transmit frequency. This will require the use of two simultaneous downlink frequencies. All frequencies are in S band. The Lunar Surface Phase is expected to last no longer than 14 days. Depending on shadowing at the landing site, but at the conclusion of a lunar day (29 Earth days) Intuitive Machines will make additional attempts to communicate with the spacecraft to determine if the NOVA-C survived the harsh conditions subsequent to sunrise after the first lunar night post landing. Intuitive Machines will request appropriate authority in the event that subsequent operations are possible and desired beyond the expiration of this authorization (~60 days).

A.3 NOVA-C OVERVIEW

The NOVA-C is a three-axis stabilized bus, with a dry mass of 813 kg and an approximate wet mass of 2248 kg, measuring 4.3m x 4.0m x 4.8m high (including landing gear). Five fixed body-mounted solar panels provide an average of 600 W of power, stored in Li-ion batteries, with a total energy capacity of 1554 Watt-hours, and an unregulated 28 volts direct current ("VDC") bus voltage. Attitude determination and control is achieved with redundant inertial measurement units ("IMU"), star trackers, and a dual-redundant cold gas (pressurized helium) reaction control system ("RCS"). The NOVA-C will be separated from the Falcon 9 launch vehicle via a RUAG zero-debris deployment system. A representative view of the NOVA-C is shown in Figure A.3-1.

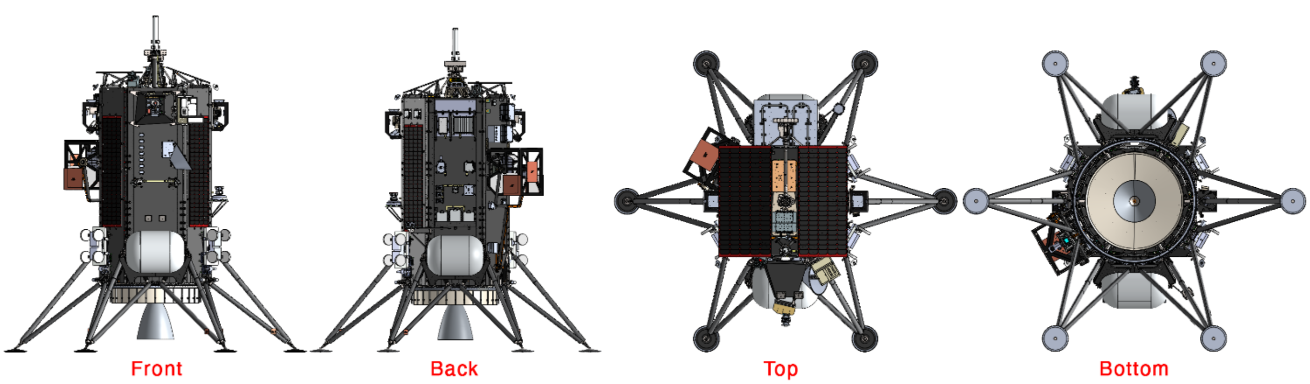


Figure A.3-1 Side views of the NOVA-C

A.4 ORBITAL PARAMETERS

The NOVA-C will be inserted into a direct trajectory to the Moon by the SpaceX Falcon 9 booster. Deployment will occur at an altitude of approximately 650 km. The deployment orbit will be approximately 380,000 km x 200 km in altitude, with an inclination of approximately 28 degrees. The bulk of operations will occur in transit, and then on the surface of the Moon. A lunar orbit insertion ("LOI") burn will achieve a circular 100 km x 100 km low lunar orbit (LLO).

A.5 SPECTRUM USAGE

The NOVA-C will use S-Band frequencies for transmit and receive operations during the IM-3 Mission. TT&C uplink operations will use a single frequency in the 2025-2110 MHz band, while TT&C and data downlink operations will use two frequencies (one for each transmitter) in the 2200-2290 MHz band. Lunar surface links between the Nova-C lander and the LVx rover will be in the 2400-2417 MHz and 2450-2483.5 MHz bands. Table A.5-1 provides channel, frequency, and bandwidth of the NOVA-C transmit beams.[2] All direct-to-Earth communications utilize right-hand circular polarization ("RHCP"). The lander-to-rover links use linear polarization. Uplink and downlink center frequencies follow the convention for spacecraft transponder turnaround ratios as specified in NASA's DNS No.810-005, 201. For S-Band downlink to S-Band uplink this ratio is 240/221. IM-3 frequency pairs are as follows:

Downlink: 2210.6 MHz; Uplink: 2035.59416 MHz

Downlink: 2250 MHz; no corresponding uplink

Table A.5-1: Transmitting (Downlink) Channels[3]

Schedule S Channel ID	Channel Bandwidth, MHz	Center Frequency, MHz	Service Link or TT&C
TX01	.005	2210.6	TT&C
TX02	.03	2210.6	TT&C
TX03	.075	2210.6	TT&C
TX04	.125	2210.6	TT&C
TX05	.275	2210.6	TT&C
TX06	.175	2250	Service
TX07	.35	2250	Service
TX08	.5	2250	Service
TX09	.625	2250	Service
TX10	1.5	2250	Service
TX11	2.6	2250	Service
TX12	5.5	2250	Service
TX13	8	2250	Service

[2] *See* 47 C.F.R. § 25.114(c)(4)(i)-(ii).

[3] Due to limitations in the Schedule S software, only a single service category may be entered for transmitting channels. Intuitive Machines clarifies that the modes with bandwidth greater than or equal to 275 kHz can carry telemetry or data (service).

Schedule S Channel ID	Channel Bandwidth, MHz	Center Frequency, MHz	Service Link or TT&C
TX14	10.7	2250	Service
TR01	4	2411	Service
TR02	4	2472	Service

Table A.5-2 provides corresponding channel frequency and bandwidth of the NOVA-C receive beams.

Table A.5-2: Receiving (Uplink) Channels

Schedule S Channel ID	Channel Bandwidth, MHz	Center Frequency, MHz	Service Link or TT&C
RX01	.03	2035.59416	TT&C
RX02	.075	2035.59416	TT&C
RX03	.202	2035.59416	TT&C
RUM1	.004	2035.59416	TT&C
RR01	4	2411	Service
RR02	4	2472	Service

All communications with the NOVA-C are strictly for spacecraft control and payload data collection. In the United States, uplink and downlink will be handled at two ground station sites, Morehead State University ("Morehead") in Kentucky[4] and the DSN site at Goldstone, CA. TT&C uplink consists of two modes: one with ranging on and one with ranging off.

Data downlink operations will be centered at 2210.6 MHz and 2250 MHz and encompass several channel bandwidths as shown in Table A.5-1. Both TT&C and data downlinks can be transmitted via the low-gain hemi antennas or the high gain antenna (HGA).

A.6 LUNAR TELEMETRY, TRACKING, AND CONTROL

The NOVA-C flight computer will use the Consultative Committee for Space Data Systems ("CCSDS") standard 131.0-B-1 regarding TM Synchronization and Channel Coding as well as CCSDS 732.0-B-3 regarding the Advanced Orbiting Systems ("AOS") Space Data Link Protocol for telemetry formatting. The NOVA-C flight computer will encrypt all data before it is sent to the radios for transmission to Earth and decrypt all data sent from Earth.

When the NOVA-C transmits over S-Band, the RF signals are received by the LTN, which is comprised of a geographically diverse set of large dish antennas under contract with Intuitive Machines as shown in Table A.10.1-1.

[4] Morehead will separately seek special temporary authority to support the IM-3 mission. Intuitive Machines will support Morehead in this effort as appropriate.

TT&C uplink operations will be centered at 2035.59416 MHz via the Thales transceivers using low-gain antennas, with variable bandwidth channels for ranging-on and ranging-off modes as described below. TT&C downlink operations will be centered at 2210.6 MHz for the Thales transceivers and at 2250 MHz for the Quasonix transmitters and transmit primarily using the low-gain antennas at variable bandwidth, with contingency operations on the high-gain antenna, as needed.

A.7 COMMUNICATIONS PACKAGE

The NOVA-C will have six low-gain hemispheric antennas and one high-gain antenna used primarily for lunar operations. The parameters for these antennas are set forth in Table A.7-1.

Table A.7-1: Parameters of the NOVA-C Antennas

Antenna Type	Quantity	Mid-band RX Gain, dBi	Mid-band TX Gain, dBi
Hemispheric (Low-gain)	4	6.5	5.6
Helix (High-gain)	1	14.8	15.6
Patch	1	5.9	5.9

Figure A.7-1 shows the antenna placements and directions on the NOVA-C.

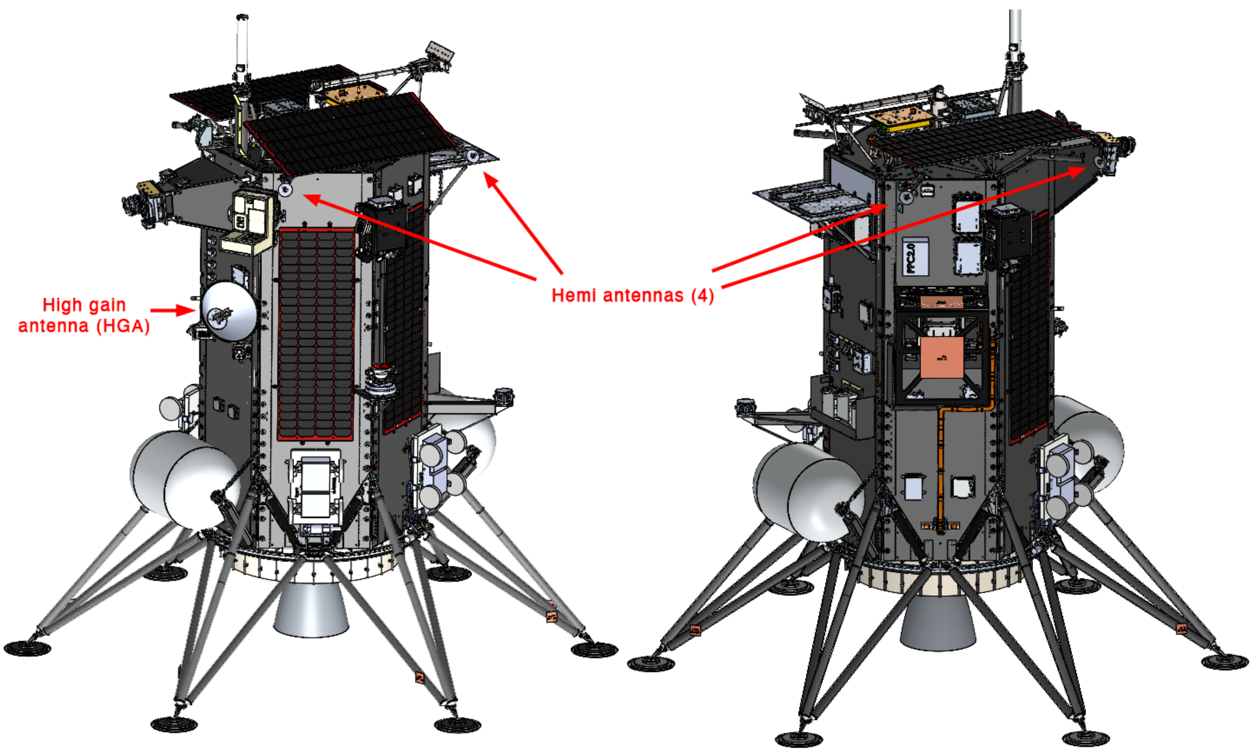


Figure A.7-1: NOVA-C Antenna Placements and Directions

A.7.1 Thales Transceivers

The Thales transceivers are fixed frequency units that transmit and receive in S-band. The modulation scheme is BPSK for both uplink and downlink operations. The Thales transceivers use the synchronous RS-422 interface standard for telemetry and have various output types for TT&C and status data. The transceivers are compatible with the European Space Agency's ("ESA") two-tone system for ranging. The Thales transceivers have 8W transmit power.

The parameters for the Thales transceivers are provided in Table A.7.1-1 below.

Table A.7.1-1: Thales Transceiver Modes

Mode	Center Frequency, MHz	Polarization	Bandwidth	Modulation
TT&C Uplink (Ranging ON)	2035.59416	RHCP	202 kHz	BPSK/PM
TT&C Uplink (Ranging OFF)	2035.59416	RHCP	75 kHz	BPSK/PM
TT&C Downlink (Ranging ON)	2210.6	RHCP	275 kHz	BPSK/PM
TT&C Downlink (Ranging OFF)	2210.6	RHCP	75 kHz	BPSK/PM

A.7.2 Quasonix Transmitters

The Quasonix transmitters are tunable and transmit only. The modulation scheme is OQPSK. The Quasonix transmitters use CCSDS protocol for downlink and interface to NOVA-C via synchronous RS-422 interface standard for telemetry, and asynchronous RS-422 for TT&C and status information. They are reconfigurable by command. The expected configuration will be 25W RF transmit power, with encoded bit rates between 62.5 kbps and 4.25 Mbps.

The parameters for the Quasonix transmitters are provided in Table A.7.2-1 below.

Table A.7.2-1 Quasonix Transmitter Parameters

Parameter	Quasonix Downlink
Frequency	2250 MHz
Polarization	RHCP
RF Bandwidth	175 kHz to 10.7 MHz
Modulation scheme	OQPSK
Modulation index	N/A

A.7.3 Microhard Hexa-band Digital Data Link

The Nova-C has one dedicated Microhard Hexa-band transceiver for communication with the Lunar Vertex rover while on the lunar surface. The transceiver is a 2x2 multiple-input multiple-output (MIMO) wireless digital data link that will operate on two distinct S band frequencies (2411 MHz and 2472 MHz). Maximum output power is 1W which will be coupled with either of two dedicated patch antennas (5.9 dBi) for a maximum EIRP of 5.9 dBW.

A.7.4 High-Gain Antenna

There is one high-gain antenna that will be used primarily for lunar surface operations, but it may also be used intermittently during transit and lunar orbit phases. The high-gain antenna is an axial mode helical antenna with a conical reflector and has a mid-band transmit gain of 15.6 dBi and a mid-band receive gain of 14.8 dBi. It is expected that the high-gain antenna will be used primarily with the Quasonix transmitters, but RF switching allows for the Thales transceiver to use the high-gain antenna for transmit or receive.

Figure A.7.3-1: NOVA-C High-Gain Antenna

A.7.5 Hemispheric Antennas

Four turnstile hemispheric antennas are located in various locations on the NOVA-C, with only one active at any time. RF switches allow for switching between the various antennas. Peak transmit gain is 5.6 dBi at 2250 MHz. It is expected that the hemi antennas will be used primarily with the Thales transceivers, but RF switching also allows for use by the Quasonix transmitters.

Figure A.7.4-1: NOVA-C Hemispherical Antenna

A.7.6 Patch Antennas

Two small patch antennas, approximately 55 x 55 x 5 mm, are mounted on NOVA-C Panel E and angled to be in view of the lunar surface. They provide 5.9 dBi of gain and will be used to communicate with the Lunar Vertex rover once the rover is deployed.

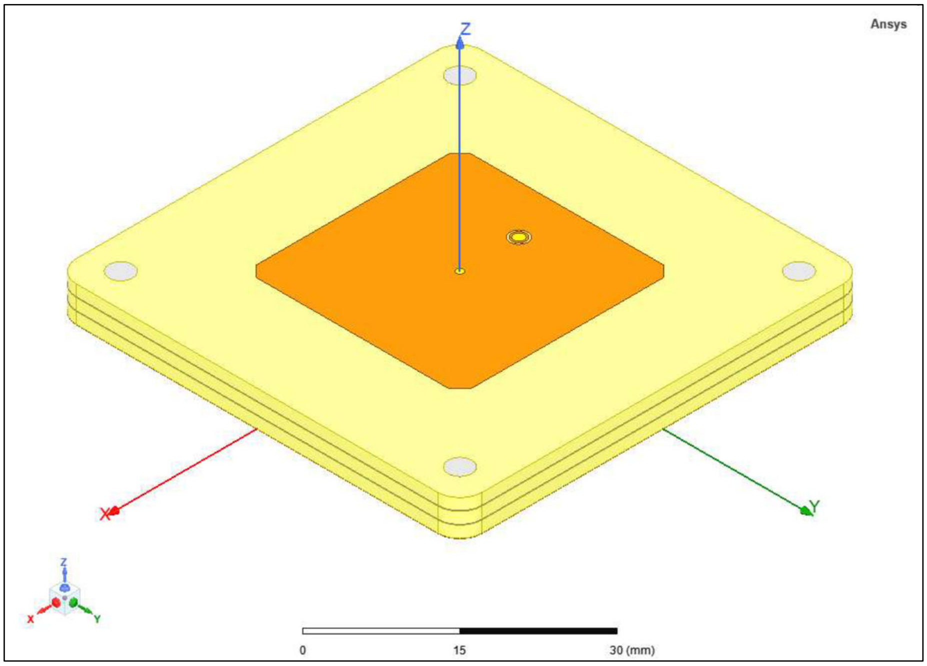


Figure A.7.4-2: NOVA-C Patch Antenna

A.8 PREDICTED SPACE STATION ANTENNA GAIN CONTOURS

Antenna gain contours for IM-3 NOVA-C are provided in GXT format as part of this application and also reproduced below. All antennas are body-mounted on the NOVA-C. Antenna pointing is limited by the attitude control systems of the NOVA-C. The low-gain antennas are hemispherical and provide roughly 180 degrees of coverage. The high-gain antenna will be pointed at specific ground stations during Earth-Moon transit and remain in a fixed, Earth-pointing orientation on the lunar surface.

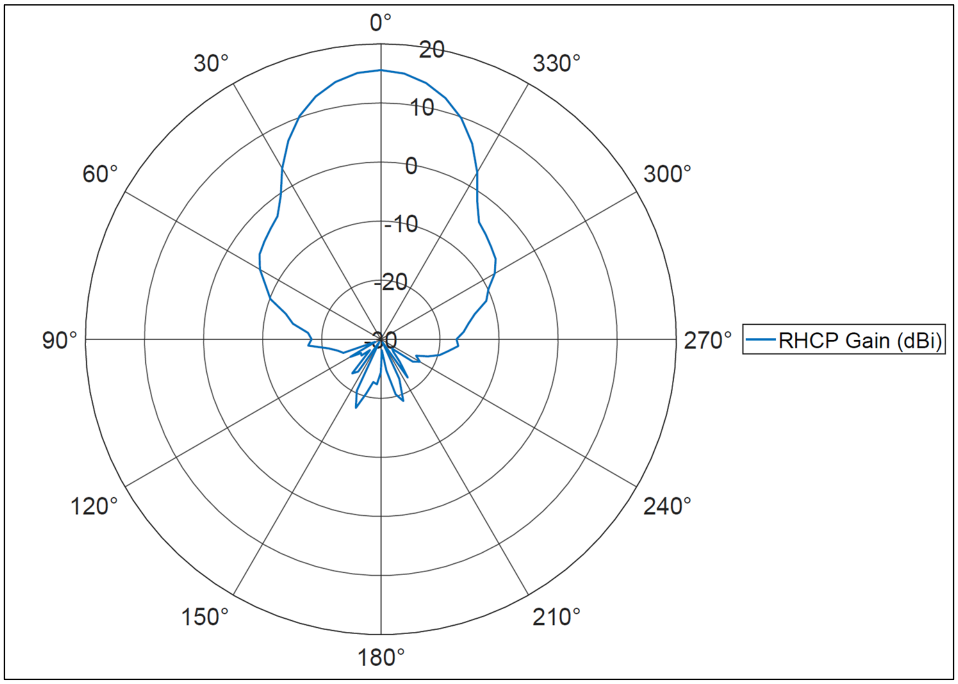


Figure A.8-1: NOVA-C High-Gain Antenna TX Contour

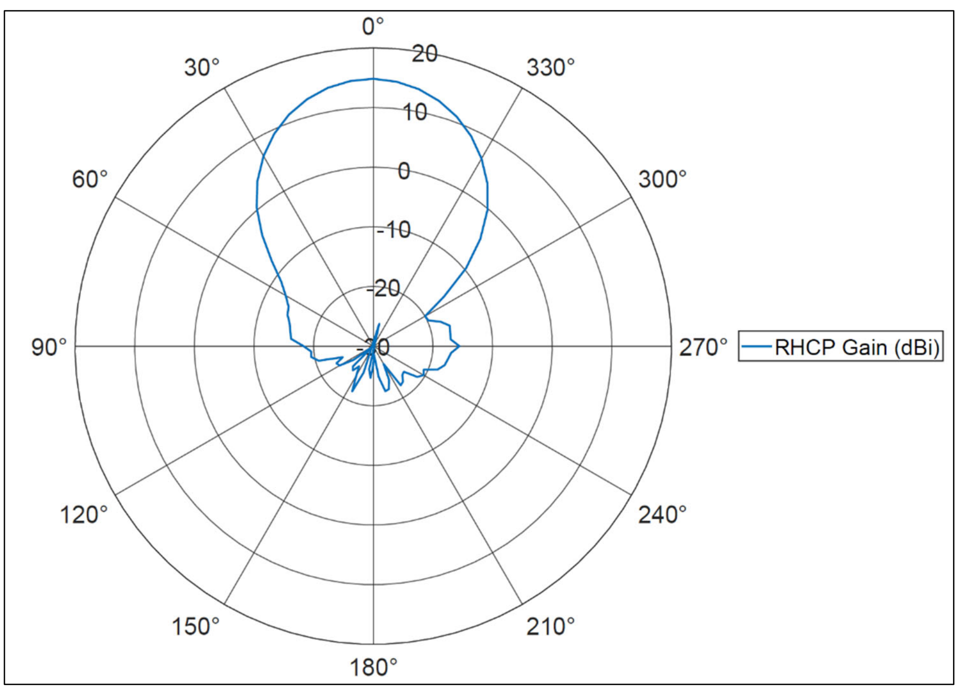


Figure A.8-2: NOVA-C High-Gain Antenna RX Contour

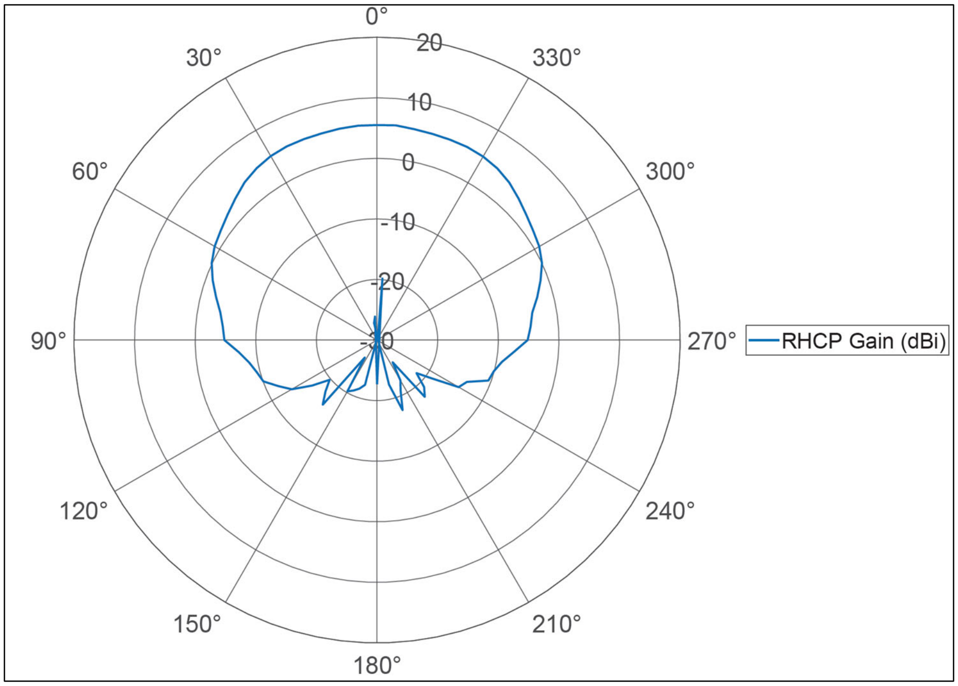


Figure A.8-3: NOVA-C Low-Gain Antenna TX Contour

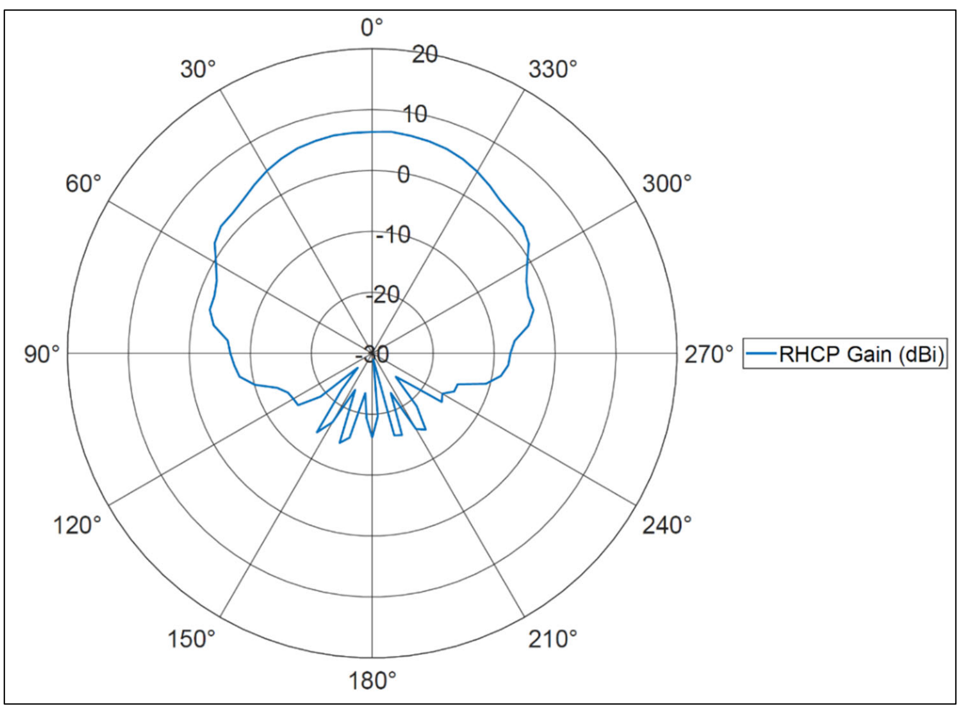


Figure A.8-4: NOVA-C Low-Gain Antenna RX Contour

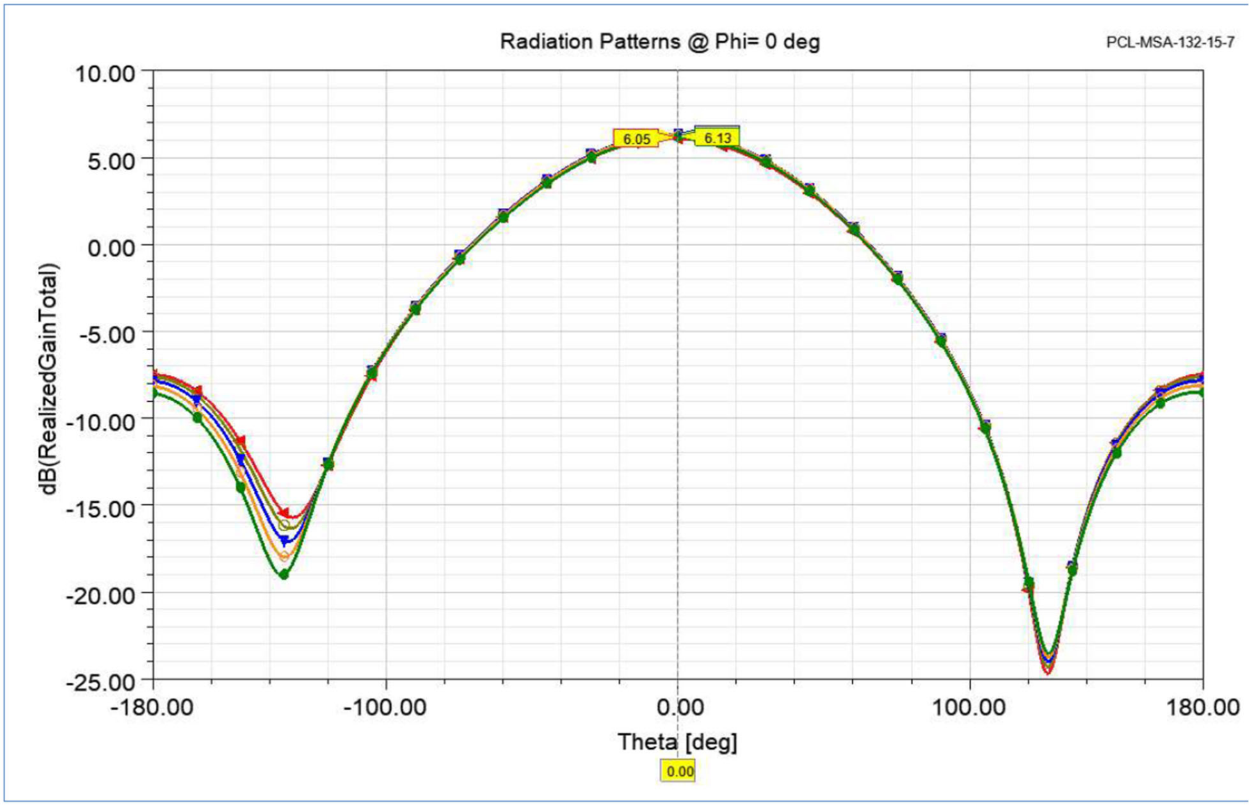
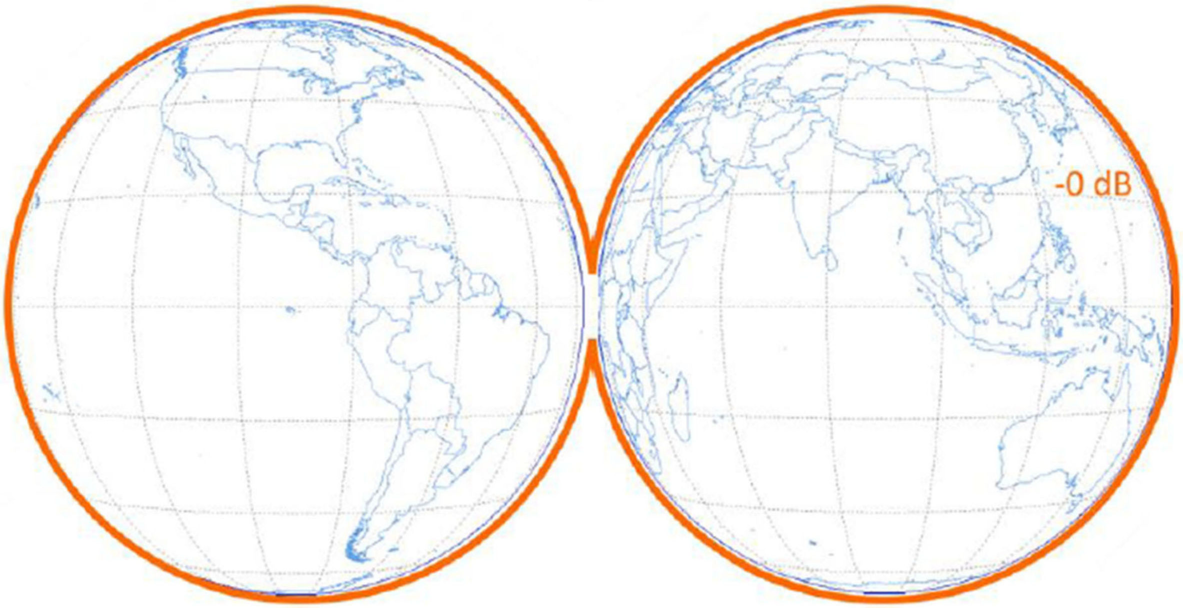


Figure A.8-4: NOVA-C Patch Antenna TX and RX Contour

It should be noted that at lunar distance, the full face of the Earth lies well within the flat, peak-gain regions of the transmit and receive beams of the high-gain and low-gain antenna boresights at 0 dB. The 2-20 dB loss contours lie far off the Earth's surface and therefore are not shown in the plot below as they contribute nothing to the PFD compliance criteria. As a result, a single antenna gain contour depicting performance of the transmit and receive beams of the high-gain and low-gain antennas is provided in Figure A.8-5.

Figure A.8-5: Antenna Gain Contour Plot at Lunar Distance for NOVA-C High/Low Gain Transmit and Receive Antennas Relative to Peak Gain



A.9 PAYLOADS

A.9.1. Cooperative Autonomous Distributed Robotic Exploration (CADRE)

The CADRE payload consists of a suite of components: three rovers, a base station, and a Situational Awareness Camera Assembly. This suite will create a network that will work together to explore the Moon in an experiment to demonstrate new technology. Communicating via the L-band (1718-1722 MHz) mesh network radios[5] with each other and a base station aboard the Nova-C, the rovers will be largely autonomous, making decisions and acting without the need for human intervention. The SACA will continually monitor the progress of the rovers by rotating around the lander through a motorized gimbal.

A.9.2. LUNAR SURFACE ENVIRONMENT MONITOR (LUSEM)

The LuSEM payload consists of two pairs of solid-state telescopes that is designed to detect high-energy particles, such as solar energetic protons and secondary radiation, as well as materials in the geomagnetic tail on the lunar surface. Each pair consists of a nadir-viewing and zenith-viewing telescope that will take measurements of incoming and reflected high-energy particles at the same time.

A.9.3. Vertex Camera Array (VCA)

The VCA payload consists of three separate camera clusters containing three cameras each. These cameras will survey the site geology and take images used to assess the photometric

[5] NASA assumes responsibility for obtaining appropriate authority to operate on the 1718-1722 MHz on the lunar surface, and Intuitive Machines will provide appropriate authorization details from NTIA under separate cover when available.

character of the lunar surface. This will contribute to an understanding of the cause of the blast-zone optical modification observed from orbit and texture related properties of the lunar swirls. The LVx-VCA will also obtain images of the LVx-Rover when it is close to the lander and later at greater distances on its traverse route.

A.9.4. Vector Magnetometer- Lander (VML)

The VML payload is composed of a fixed mast with a dual ring-core fluxgate sensor on the tip and four Commercial Off The Shelf (COTS) mini magnetometers arrayed near the base of the mast. VML will measure magnetic fields smaller than 1 nanoTesla (nT) during the lander descent phase and on the surface.

A.9.5. Magnetic Anomaly Plasma Spectrometer (MAPS)

The MAPS payload is an ion and electron electrostatic analyzer used to characterize incident ions and electrons at the lunar surface. The primary objective is to study the interaction of the solar wind with surface materials on the Moon, aiming to understand the origin of the sinuous patterns of bright and dark soil, known as lunar swirls, that correspond with anomalous regions of magnetic rocks.

A.9.6. Lunar Vertex (LVx) Rover

The LVx Rover payload is used to provide mobility to two smaller payloads: the Vector Magnetometer Rover (VMR) and the Rover Multispectral Microscope (RMM). These payloads will characterize the magnetic field experienced around the lander and capture images of the lunar surface. The Nova-C lander has a dedicated S-Band radio that will alternate between 2472 MHz and 2411 MHz with a 4 MHz bandwidth to communicate with the Lunar Vertex (LVx) Rover's primary and secondary radios. Communication will happen during lunar surface operations to transfer scientific data and rover telemetry between the rover and lander. The data is then relayed through the lander's S band communication system back to Earth.

A.9.7. Moon Laser Instrumentation for General relativity/geophysics High-accuracy Tests (MoonLIGHT)

The MoonLIGHT payload is a 3" fused silica laser reflector that will reflect laser measurements back to Earth. It will also serve as a fiducial marker for the lander on the lunar surface and for improving navigation of future orbiters and landers.

A.9.8. Virtual Reality Camera System (VRCS)

The VRCS payload consists of a six camera system that will capture high definition images and video to create an immersive virtual reality experience from lunar orbit and on the lunar surface.

A.9.9. Space Science & Technology Evaluation Facility – First Flight (SSTEF-1)

The Aegis Aerospace SSTEF-1 payload consists of multiple Technology Demonstration Experiments (TDEs). The TDEs are an implementation of hardware, electronics and software that will operate in the lunar environment and achieve a technology and/or science objective. The payload includes an enclosed housing that contains two 3D-printed antennas that will communicate via Ku band between 14-15 GHz.[6]

A.9.10. Australian Lunar Experiment Promoting Horticulture (ALEPH-1)

The ALEPH-1 payload will demonstrate the growth of a Rapeseed seedling on the lunar surface. The ALEPH-1 payload will house the seedling and a camera to monitor its growth to help understand plant growth on the lunar surface.

A.9.11. Public Affairs Office (PAO) Cameras

There are a total of 7 PAO cameras for the IM-3 Mission, six on the NOVA-C panels and one on the RCS (Reaction Control System) boom. These cameras will give a 360-degree view of the NOVA-C lander at critical portions of the mission for IM public affairs. These cameras will also monitor the deployment of both the CADRE and LVx Rovers.

A.9.12. Laser RetroReflector for Insight (LaRRI)

The LaRRI payload is used to reflect laser light from orbiting spacecrafts to identify the exact location of the Nova-C lander. This will assist in creating a geodetic network of the moon.

A.10 EARTH STATION NETWORK

A.10.1 Earth Stations

The NOVA-C will communicate with various earth stations during transit and while on the lunar surface to ensure 24/7 coverage. Tables A.10-1 and A.10-2 below catalogs these sites.

Table A.10-1: LTN Antenna Network

Antenna	Ground Station	Location	Size (meters)
DSS17	Morehead State University Space Sciences Center	Morehead, KY USA	21
PARKES	Parkes Observatory (Rx only)	Parkes, NSW Australia	64
GHY6	Goonhilly Satellite Earth Station	Helston, UK	32
D32	Indian Deep Space Network	Byalalu, Karnataka, India	32
D18	Indian Deep Space Network	Byalalu, Karnataka, India	18.3
SI1	Singapore	Singapore	9.1
MA1	Mauritius	Port Luis, Mauritius	7.3
DU1	Dubai	UAE	7.3
KRU1	Kourou	French Guiana	15
HBK1	Hartebeesthoek	Hartebeesthoek, South Africa	25.9
HBK2	Hartebeesthoek	Hartebeesthoek, South Africa	12.2

[6] Aegis Aerospace will apply for separate FCC authorization for these frequencies. Intuitive Machines will not permit operations in the 14.0-15.0 GHz absent an affirmative demonstration that the FCC has approved this hosted payload.

Table A.10-2: DSN Antenna Network

Antenna	Ground Station	Location	Size (meters)
GS DSS-24	Goldstone DSN	Goldstone, CA	34
CB DSS-34	Canberra DSN	Canberra, Australia	34
MD DSS-53	Madrid DSN	Madrid, Spain	34

Some of the ground stations will provide access to baseband units connected to NOVA Control to send commands and receive telemetry. At least three of the sites will host baseband units provided by Intuitive Machines which allows for more control in testing the terrestrial interfaces and raises confidence in mission success related to the communications systems.

A.11 POWER FLUX DENSITY ANALYSIS AND SPECTRUM COMPATIBILITY

The NOVA-C is not in any of the services, will not communicate in any of the frequency bands, and will not be located in any of the orbits, as defined in 47 C.F.R. § 25.208 (b)-(r). Therefore, the power flux density limit requirements do not apply. Intuitive Machines will coordinate with NASA and other relevant government agencies to ensure operations will not cause harmful interference.

A.12 CESSATION OF EMISSIONS

Each active spacecraft transmission chain can be individually turned on and off by ground telecommand, thereby causing cessation of emissions from the NOVA-C, as required by Section 25.207 of the Commission's rules.

A.13 FREQUENCY TOLERANCE

The frequency tolerance requirements of Section 25.202(e) that the carrier frequency of each space station transmitter be maintained within 0.002% of the reference frequency will be met. The technical specifications for the Quasonix transmitter indicate that for all bandwidths selected (*see* Table A.5-1 above for list of bandwidths), the carrier frequency will be maintained to within 0.0006%. Likewise, the Thales transceiver technical specifications indicate for all bandwidths selected (*see* Tables A.5-1 and A.5-2 above for list of bandwidths), the transmitter maintains a frequency variation of +/-33 kHz, or maintenance to within 0.0015%..

A.14 OUT-OF-BAND EMISSIONS

The NOVA-C lunar lander will comply with the Commission’s rules regarding out-of-band emissions contained in Section 25.202(f).

A.15 TELEMETRY MARKER

The NOVA-C will be identifiable by a unique signal-based telemetry marker distinguishing it from other space stations or space objects consistent with Section 25.123(b)(3).

A.16 ITU FILINGS & COMPLIANCE

Intuitive Machines will prepare and file with the International Telecommunication Union an ("ITU") Advance Publication Information submission for its proposed system, as noted in the Narrative.[7]

IM-3 will operate in full compliance with the ITU power flux density ("PFD") limits contained in Article 21, Table 21-4 of the ITU Radio Regulations. Table A.16-1 below provides the maximum PFD values for IM-3's two HGA transmit Beams, along with the corresponding Article 21 limits. Distance used for the PFD calculation was 363,300 km, the nominal Earth-Moon distance. Thales Beam THGA has signal bandwidths ranging from 5 kHz to 275 kHz. A value of 5 kHz was used for the PFD calculations. Quasonix Beam QHGA has signal bandwidths ranging from 175 kHz to 10.7 MHz. A value of 175 kHz was used for the PFD calculations.

Table A.16-1: ITU Article 21-4, Table 21-4 PFD Limits

Article 21, Table 21-4 PFD Limits					
Frequency Band	**Service**	**Limit in dB(W/m^2) for angles of**			**Reference Bandwidth**
		0°-5°	**5°-25°**	**25°-90°**	4 kHz
2200-2300 MHz	Space research Space operation	-154	$-154 + 0.5(\delta - 5)$	-144	

				Max Power Flux Density, dBW/m^2/4 kHz					
	Schedule S Beam ID	**Max EIRP, dBW**	**Signal BW, kHz**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-90**
Thales, HGA	THGA	24.1	5	-159.2	159.2	-159.2	-159.2	-159.2	-159.1
Quasonix, HGA	QHGA	29.1	175	-169.7	-169.6	-169.6	-169.6	-169.6	-169.5

[7] *Id.*

A.17 ORBITAL DEBRIS MITIGATION[8]

Intuitive Machines provides the following information, using NASA Debris Assessment Software to perform relevant calculations, to support the Section 25.123 certifications related to orbital debris mitigation, and set forth in in the Narrative.[9] Intuitive Machines will continue to stay current with the Space Situational Awareness community and technology and, if appropriate, Intuitive Machines will modify its orbital debris mitigation protocols.

A.17.1 Mission Overview

The IM-3 mission will consist of a single Lunar lander, NOVA-C, launched from a SpaceX Falcon 9 rocket. After separation from the launch vehicle, NOVA-C will fire its thrusters to enter into a low-lunar orbit (LLO), lasting 1-3 days depending on exact launch date. NOVA-C will spend 1-3 days of loiter before landing. While the primary mission ends at the conclusion of the first Lunar day on the Lunar surface, the official end of mission (EOM) will occur when the electrical power system (EPS) is no longer sufficient to support Lunar surface operations during a Lunar day.

A.17.2 Operational Orbital Debris

The NOVA-C will be released from a Falcon 9 launch vehicle using a RUAG low shock, zero-debris deployment system. No other mechanism will be deployed until the NOVA-C lander is on the Lunar surface. NOVA-C and its payloads will not release any operational debris while in orbit. Any planned releases on the lunar surface as described in the Narrative do not result in any risk of orbital debris collisions with any other space systems.

A.17.3 Orbital Debris Generated from Accidental Explosion

Based on the Failure Mode and Effects Analysis (FMEA) conducted by Intuitive Machines for battery and propulsion system explosion, there is no credible scenario that would result in spacecraft breakup during normal deployment and operations. The FMEA evaluated risks associated with battery overcharge, short circuiting and high temperatures as well as risks associated with over pressurization and valve, ignition and other material failures of the propulsion system, concluding that the expected probability of explosion for all credible failure modes of NOVA-C is less than 0.001.

A.17.4 Large Object Collision Probability

The large object impact and debris generation probability is calculated at 0.000000025, based upon the worst-case scenario where NOVA-C is launched into a trans-lunar orbit and must passively deorbit into the atmosphere due to failures**.**

[8] *See Smallsat Order*, 34 FCC Rcd at 13107 (declining to specify a single format such as the Orbital Debris Assessment Report to provide applicants with flexibility, with the expectation that all applicants use high fidelity modeling tools to perform the calculations necessary to address the various certifications required by the Commission's Rules).

[9] *See* Legal Narrative at Table 3.

Upon receipt of a space situational awareness conjunction warning, Intuitive Machines will review conjunction warnings, coordinate physical operations of the NOVA-C with any operator using similar orbits, and, if necessary, mitigate collision risks to minimize operational impacts.

A.17.5 Design for Post-Mission Passivation and Disposal

The NOVA-C lander is designed to soft land on the lunar surface and disposal will be in situ on the Moon in the Reiner Gamma region. The spacecraft is powered by 3 battery boxes each featuring 72 P20 lithium-ion batteries (216 cells total in the spacecraft) fed by SpectroLab solar cells and run to battery depletion in the Lunar night. NOVA-C's helium pressurized methane and liquid oxygen propellant system will be vented upon touchdown just prior to a minimum of 14 days of surface operation after which the spacecraft will be operated until it is unresponsive. The spacecraft uses cold gas helium for reaction control in flight and this helium is drawn from the same reservoirs as the main propulsion system. This reaction control subsystem (RCS) will be passivated when the propulsion systems are vented on the surface. While the primary mission ends at the conclusion of the first Lunar day on the Lunar surface, the official end of mission (EOM) will occur when the electrical power system (EPS) is no longer sufficient to support Lunar surface operations during a Lunar day.

Under planned launch conditions, NOVA-C will transit to Lunar orbit, land on the Lunar surface and never cause any form of orbital debris or human casualty risk. Under nominal operational conditions, the NOVA-C will be abandoned on the Lunar surface. The probability that either a Falcon 9 booster Trans Lunar Injection (TLI) or PMD burn can be conducted within the first 19 hours after launch has been estimated to be significantly greater than 90% based on a basic evaluation of single point and redundant failure paths in the critical systems needed to do a pointed and controlled engine firing. If the mission cannot continue from the trans-lunar insertion orbit, a PMD maneuver will be attempted. It can be commanded to employ up to 3000 m/s of delta-V to conduct a PMD burn to assure that atmospheric reentry occurs in a location that is safely away from human inhabitants. Under worst-case conditions, the NOVA-C will deorbit naturally into the Earth's atmosphere within 3 months of launch.

A.18 REMOTE SENSING CAPABILITIES

The NOVA-C involved in the instant mission includes the following cameras or optical instruments identified in Table A.18-1.

Table A.18-1: Optical Instrument Inventory

Device	No. of Units	Description
Panel-mounted Public Affairs Office (PAO) cameras	6	Six cameras mounted to the panels of NOVA-C. They will primarily capture stereo imaging of rover deployments on the lunar surface. While these cameras are intended to monitor the health of the spacecraft, they may also capture incidental images of the Earth's surface. IM self-reports the RCS cameras on NOVA-C landers as PAC devices.
RCS boom-mounted Public Affairs Office camera	1	Small RCS (Reaction Control System) camera mounted on compact booms attached to the top of the lander. One camera on the RCS will capture deployment. While these cameras are intended to monitor the health of the spacecraft, they may also capture incidental images of the Earth's surface. IM self-reports the RCS cameras on NOVA-C landers as PAC devices
Virtual Reality Camera System (VRCS)	6	High-definition images and video from lunar orbit and the lunar surface to create a virtual reality experience.
Vertex Camera Array (VCA)	9	Three sets of three-color cameras to survey site geology and take images used to assess the photometric character of the lunar surface.
Australian Lunar Experiment Promoting Horticulture (ALEPH-1)	1	Monitor the growth of plant seedlings within the ALEPH housing on the lunar surface.
Cooperative Autonomous Distributed Robotic Exploration (CADRE)	6	There are two cameras per rover (total of six) that will provide situational awareness, visuals of deployments and 3D representation of the lunar surface. There is also a 3-camera head system that has the ability to move about a 2-axis gimbal to give a 360 degree field of view on the lunar surface.
Lunar Vertex Rover (LVx)	4	Capture images and video of the lunar surface.

Device	No. of Units	Description
Space Science & Technology Evaluation Facility (SSTEF-1)	1	Camera that will capture images of the payload housing unit to monitor the Technology Demonstration Experiments onboard. Camera will also capture images on the lunar surface.

Certain cameras referenced above may inadvertently capture images of the Earth while the lander takes photographs of itself or its lunar environment. Such images do not contain data that can be enhanced to show topographical features on Earth, and Intuitive Machines is not making them available for sale. Such images with a distant and removed Earth in the far background may be used for marketing purposes, but they have no other meaningful utility. No camera involved in the instant mission is intended to image the Earth.

Intuitive Machines will separately submit a request to the National Oceanic and Atmospheric Administration's (NOAA) Commercial Remote Sensing Regulatory Affairs (CRSRA) to reaffirm that no camera involved in the instant mission qualifies as an Earth imaging instrument under 15 C.F.R. § 960.

A.19 NASA Planetary Protection Submission

Intuitive Machines has inventoried all organic materials on the NOVA-C, and will make a separate submission to NASA's Planetary Protection Office to ensure compliance with NASA NID 8715.129 concerning robotic extraterrestrial missions to the lunar surface.

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge and belief.

/s/ Jason Soloff

Jason Soloff
Chief Engineer
Intuitive Machines LLC