IM-1 Lunar Lander Mission

Intuitive Machines, LLC ("IM") is seeking to launch and operate the NOVA-C Lunar Lander ("NOVA-C") spacecraft for approximately 20 days in the 2025-2110 MHz and 2200-2290 MHz bands (the "IM-1 mission"). The IM-1 is part of the Commercial Lunar Payload Services ("CLPS") program sponsored by National Aeronautics and Space Administration ("NASA") to explore the surface of the Moon. The NOVA-C spacecraft will deliver several NASA and several commercial payloads to the lunar surface, including operations that will advance important U.S. commercial, government, and scientific interests.

Spacecraft Description: The NOVA-C spacecraft is a 3-axis stabilized bus, with an approximate wet mass of 1908 kg, measuring 2.19 m x 2.385 m x 3.938 m. Three fixed body-mounted solar panels provide a maximum of 788 W of power, stored in Li-ion batteries, with a total energy capacity of 1554 Wh, and an unregulated 28 VDC bus voltage. Attitude determination and control is achieved with redundant inertial measurement units ("IMUs"), star trackers, and a dual-redundant cold-gas (pressurized helium) reaction control system ("RCS"). The spacecraft will be separated from the Falcon 9 launch vehicle via a RUAG zero-debris deployment system.

Spectrum Usage: The NOVA-C spacecraft will transmit and receive using the licensed S-Band frequencies during the planned mission, including: (i) 2025-2110 MHz band (Earth-to-space); and (ii) 2200-2290 MHz band (space-to-Earth). All such operations will be appropriately coordinated with incumbent Federal users. Two commercial payloads on the spacecraft will communicate with NOVA-C during lunar surface operations via 802.11ac Wi-Fi frequencies in the 5.5-5.85 GHz band using off-the-shelf equipment.

The NOVA-C spacecraft utilizes four transmit (downlink) and one receive (uplink) beams through combinations of two 7W transceivers and two 25W transmitters in conjunction with four low-gain hemispheric antennas and one high-gain antenna used primarily for lunar operations. Table 1, below, lists technical information for each beam configuration in the uplink and downlink directions.

Table 1: NOVA-C Beams

Beam ID	7W Transceiver with Hemi. Antenna (Tx/ Downlink)	7W Transceiver with High-Gain Antenna (Tx/Downlink)	25W Transmitter with Hemi. Antenna (Tx/Downlink)	25W Transmitter with High-Gain Antenna (Tx/Downlink)	7W Transceiver with Hemi. Antenna (Rx/Uplink)
Beam Frequency (MHz)	2200-2290	2200-2290	2200-2290	2200-2290	2025-2110
Beam Type	Fixed	Fixed	Fixed	Fixed	Fixed
Polarization	RHCP	RHCP	RHCP	RHCP	RHCP
Peak Gain (dBi)	5	16	5	16	5
Antenna Pointing Error (deg)	0.5	0.5	0.5	0.5	0.5
Antenna Rotational Error (deg)	1.5	0.7	1.5	0.7	1.5

Polarization Switchable	No	No	No	No	No
Polarization Alignment Relative to the Equatorial Plane (deg)	28.6	28.6	28.6	28.6	28.5
Max. Transmit EIRP Density (dBW/Hz)	-25.8	-14.8	-37.3	-26.3	N/A
Max. Transmit EIRP (dBW)	12.5	23.5	18	29	N/A
G/T at Max. Gain Point (dB/K)	N/A	N/A	N/A	N/A	-21[1]
Min. Saturation Flux Density (dBW/m^2)	N/A	N/A	N/A	N/A	-353.03
Max. Saturation Flux Density (dBW/m^2)	N/A	N/A	N/A	N/A	-288.56
Co-Pol or Cross-Pol	Co-Pol	Co-Pol	Co-Pol	Co-Pol	Co-Pol
Operational Description	Transit and Lunar Tx	Contingency Tx Only	Transit and Lunar Tx	Lunar Tx (possible use in Transit)	Transit and Lunar Rx

NASA Payloads:

Laser Retroreflector Array ("LRA"): LRA is a collection of eight retroreflectors used to precisely determine the NOVA-C's position. (Retroflectors, unlike simple plane mirrors, reflect radiation from a broad range of incident angles back to its source, with minimal scattering, and brighter reflection.)

Navigation Doppler Lidar for Precise Velocity and Range Sensing ("NDL"): The NDL is a light detection and ranging ("LIDAR") based sensor composed of a three-beam optical head and a box with electronics and photonics that provide precise velocity and range sensing during descent and landing of the lander for a soft and controlled touchdown on the Moon.

Stereo Cameras for Lunar Plume-Surface Studies ("SCALPSS") Technology: SCALPSS will capture video and still image data of the lander's plume as the plume starts to impact the lunar surface until after engine shut off.

Lunar Node 1 Navigation Demonstrator ("LN-1") Science: LN-1 is a CubeSat-sized experiment that will demonstrate autonomous navigation to support future surface and orbital operations. Operation will be in S-Band at 2256.3 MHz. NASA is obtaining a separate authorization to operate this payload. The payload has flown on the space station and is being developed at NASA Marshall.

Low-frequency Radio Observations from the Near Side Lunar Surface ("ROLSES"): ROLSES will use a low-frequency radio receiver system to determine photoelectron sheath density and scale height.

[1] The estimated G/T range is -21 dB/K to -26 dB/K whether the NOVA-C is near Moon or Earth, respectively and based on what body is contributing to noise temperatures.

Commercial Payloads as of 2 February 2021:[2]

SPACEBIT Rover: A remotely commanded rover to be deployed on the lunar surface for technology demonstration.

EagleCAM: A camera unit to be released approximately 30 meters above the surface during landing, taking pictures of the NOVA-C lander as it descends.

ILO-X: A telescope instrument including a dual-camera miniaturized lunar imaging suite that aims to capture some of the first images of the Milky Way Galaxy Center from the surface of the Moon, as well as performing technology validations – including functionality and survivability in the lunar environment.

MoonLIGHT: A passive commercial retroreflector, used for measurements from Earth.

Galactic Legacy Labs ("GLL"): A passive data cache (etched metal storage units) mounted on the spacecraft and containing information about the Earth, similar to the golden records attached to the Voyager 1 and 2 spacecraft.

Radio Frequency Mass Gauging ("RFMG"): A propellant sweeping/measuring device using a low power RF signal. This is a legacy NASA payload previously flown on the International Space Station. The device is located within the propellant tank and is an ultra-low noise source.

In addition to the payloads described above, the spacecraft will be equipped with a side mounted camera looking aft. Limited imagery from this camera used during transit and on the lunar surface may be used for press releases.

LTN Ground Stations: When the NOVA-C transmits over S-band, the RF signals are received by the Lunar Tracking Telemetry and Command network ("LTN"), which is comprised of a geographically diverse set of large dish antennas under contract with IM as shown in Table 2.[3]

Table 2: LTN Dish Network

Dish	Ground Station	Location	Size (meters)
DSS17	Morehead State University Space Sciences Center	Morehead, KY USA	21
DSS49	Parkes Observatory (Rx only)	Parkes, NSW Australia	64
GHY6	Goonhilly Satellite Earth Station	Goonhilly Downs, UK	32
IDSN32	Indian Deep Space Network	Byalalu, Karnataka, India	32
IDSN18	Indian Deep Space Network	Byalalu, Karnataka, India	18

[2] Of these commercial payloads, the SPACEBIT Rover and EagleCAM will communicate with NOVA-C through Wi-Fi frequencies, as noted above. This list of commercial payloads represents the current NOVA-C payload manifest. IM will update NASA to the extent the payload manifest changes.

[3] IM continues to evaluate and contract with ground stations for its LTN, and will provide updates to the extent this list changes, and will coordinate NOVA-C and LTN operations with NASA and FCC.

CANR15	Maspalomas Station	ESA Canary Island	15
SI1	Singapore	Singapore	9.1
DU1	Dubai	UAE	7

Operating characteristics of NOVA-C with LTN ground stations, including the Morehead ground station in the United States, are set forth in Table 3, below.

Table 3: NOVA-C Operating Characteristics with LTN Ground Stations

Emission Designator	Low Gain/ High Gain	Freq. (MHz)	Center Frequency (MHz)	BW (kHz)	Pol.	Max EIRP (dBW)	Max EIRP density (dBW/ 4KHz)	Steerable/ Shapeable	Beam peak FD (dBW/m²/ 4KHz)
THALES RX (UPLINK) MODES									
26K8G7D	LG cmd	2025-2110	2035.59416	26.8	RHCP	N/A	N/A	N/N	-158.24
10K8G7D	LG cmd	2025-2110	2035.59416	10.8	RHCP	N/A	N/A	N/N	-134.56
THALES TX (DOWNLINK) MODES									
73K6G7D	LG tlm, data	2200-2290	2210.6	73.6	RHCP	12.5	-0.15	N/N	N/A
13K5G7D	LG tlm, data	2200-2290	2210.6	13.5	RHCP	12.5	7.22	N/N	N/A
73K6G7D	HG tlm, data	2200-2290	2210.6	73.6	RHCP	23.5	10.85	N/N	N/A
QUASONIX TX (DOWNLINK MODES)									
10M8G7D	HG tlm, data	2200-2290	2250	10800	RHCP	29	-5.31	N/N	N/A
8M1G7D	HG tlm, data	2200-2290	2250	8100	RHCP	29	-4.06	N/N	N/A
5M4G7D	HG tlm, data	2200-2290	2250	5400	RHCP	29	-2.30	N/N	N/A
2M70G7D	HG tlm, data	2200-2290	2250	2700	RHCP	29	0.71	N/N	N/A
1M035G7D	HG tlm, data	2200-2290	2250	1035	RHCP	29	4.87	N/N	N/A
1M013G7D	HG tlm, data	2200-2290	2250	1013	RHCP	29	4.96	N/N	N/A
675KG7D	HG tlm, data	2200-2290	2250	675	RHCP	29	6.73	N/N	N/A
338KG7D	HG tlm, data	2200-2290	2250	338	RHCP	29	9.73	N/N	N/A
169KG7D	HG tlm, data	2200-2290	2250	169	RHCP	29	12.74	N/N	N/A
81KG7D	HG tlm, data	2200-2290	2250	81	RHCP	29	15.94	N/N	N/A
54KG7D	HG tlm, data	2200-2290	2250	54	RHCP	29	17.70	N/N	N/A
54KG7D	LG tlm, data	2200-2290	2250	54	RHCP	18	6.70	N/N	N/A