NASA Lunar Communications Relay and Navigation Systems (LCRNS) Reference Constellation 3.1

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Background

The LCRNS constellation is required to provide communications and navigation services to users in the region of the lunar south pole [1]. As such, many groups that represent end-users of LCRNS need trajectory data for the LCRNS constellation in order to perform analyses. This document is provided to supply end-users with a set of states representing the government reference Constellation design for these analyses. This reference design is not final; the final design choice belongs to Intuitive Machines (IM), under the contract to provide services to the Near Space Network (NSN) [2]. Any subsequent design updates will replace this version and will include updated version numbers for clarity.

Reference Trajectory States

In order to achieve adequate coverage of the region surrounding the lunar south pole with a small number of satellites, a class of orbits known as Elliptical Lunar Frozen Orbits (ELFO) was selected to provide longer dwell times with apolune above the south pole. This class of orbits makes use of the Earth's perturbations to provide stability in the orbit Argument of Perilune (AOP) and Eccentricity [3]. In order to ensure consistent geometry of the constellation over time, a steepest descent targeting approach was used to identify initial states with long-term average periods.

Tables 1 and 2 below offer two different representations of the constellation initial states at the reference epoch of March 01, 2027 00:00:00.000 UTC. The Moon Principal Axis frame is realized based on the JPL DE 421 planetary ephemeris. The period of these orbits is approximately 30 hours on average.

***Table 1**: LCRNS Reference Constellation Initial States in Keplerian Elements in the Moon-centered Principal Axis Frame, referenced to the J2000 Epoch.*

	SMA	ECC	INC	RAAN	AOP	TA
SV-1	11315.936501	0.691982	59.373229	321.019197	92.494031	0.000000
SV-2	11317.948675	0.691982	58.951732	320.997768	92.505016	180.000000
SV-3	11305.413654	0.691982	52.733096	81.148790	92.062891	140.049207
SV-4	11326.302154	0.691982	52.513419	81.138818	92.068945	195.992393
SV-5	11307.882863	0.691982	56.310396	204.889626	85.444071	164.007607

Table 2: *LCRNS Reference Constellation Initial States in Cartesian Elements in the Moon-centered International Celestial Reference Frame (ICRF).*

	X	Y	Z	Vx	Vy	Vz
SV-1	-198.931445	386.023132	3458.355412	-1.539867	0.022243	-0.091059
SV-2	1089.980598	-2260.918271	-18984.562823	0.280301	-0.004049	0.016575
SV-3	9187.665852	-260.470721	-8543.222759	0.273629	0.417588	-0.313828
SV-4	6484.019002	14329.883921	-7966.345594	-0.258433	0.033951	0.235264
SV-5	-5074.242314	14473.022751	-8638.530033	-0.229931	-0.026926	-0.264381

Dynamical Model for Propagation

In order to realize the long-term stability of these reference orbits, a dynamical model must be used that is consistent with the model used to generate these states. Table 3 provides the recommended dynamical model settings for propagation of these orbit states. The gravity field used for the Moon is the Grail Gravity Model (GRGM-900c). The Solar Flux used based on a constant output from the Sun of 1367 W/m^2 at 1 AU distance, and scaled based on the spacecraft distance from the Sun.

Table 3: *Recommended Dynamical Model for State Propagation*

Planetary Reference	DE 421
Gravity Field	GRGM-900c, 25x25 (Deg/Ord)
Solid Tides	Off
Point Masses	Sun, Venus, Earth, Mars, Jupiter, Saturn
Atmospheric Drag	Off
Solar Radiation Pressure	Spherical
Solar Flux	Constant, 1367 W/m^2 @ 1 AU
Cr	1.8
SV Mass	850 kg
SV Area	1 m^2

References

[1] NASA Exploration & Space Communications, "Lunar Communications Relay and Navigation Systems (LCRNS)," [Online]. Available: https://esc.gsfc.nasa.gov/projects/LCRNS. [Accessed Feb. 2025].

[2] NASA, "NASA Selects Lunar Relay Contractor for Near Space Network Services," 17 September 2024. [Online]. Available: https://www.nasa.gov/news-release/nasa-selects-lunar-relay-contractor-for-near-space-network-services/.

[3] D. Folta and D. Quinn, "Lunar Frozen Orbits," in *AIAA/AAS Astrodynamics Specalist Conference & Exhibit*, Keystone, CO, 2006.