Preliminary Design of Intuitive Machines' Lunar Data Network Constellation.

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Introduction: LunaNet is a multi-agency initiative to build an inter-operable positioning, navigation, and timing (PNT) and communication network capability for future users at the Moon. The LunaNet Interoperability Specification (LNIS) has been developed via coordination between NASA, ESA, and JAXA in order to enable any and all international partners to contribute to building coorperative infrastructure to enable future human exploration or the Moon [1][2]. Intuitive Machines (IM) has been awarded a contract under the NASA Near Space Network Services (NSNS) Lunar Communications Relay and Navigation Systems (LCRNS) Project to build a preliminary constellation of 5 satellites as the initial U.S. component of LunaNet. This paper presents an overview of the satellite constellation geometry and associated communications relay and PNT performance that will be available for lunar users during the initial operating capability phase of operations of the IM Lunar Data Network (LDN) PNT constellation.

IM LDN PNT Constellation: The five-satellite IM LDN constellation will be constructed beginning with the first of three launch phases beginning in early 2026. The first satellite (LDN-1) will launch as ridesard on the IM-3 lunar landing mission. The second and third LDN satellites will launch with IM-4 in 2027, and the final forth and fifth LDN satellites will launch with IM-5 in 2028. The LDN-1 satellite will flyby the Moon and conduct a ballistic lunar transfer (BLT) to re-rendevous with the Moon and insert into a southern elliptical frozen orbit (ELFO) approximately 120 days after launch.

LDN-1 Lunar Transfer Trajectory. After separation from the Space-X Falcon-9 rocket both the IM-3 lunar lander and the LDN-1 PNT satellite will be on translunar trajectories designed to intercept to Moon's orbit within 5-6 days. At lunar arrival the IM-3 lunar lander will conduct a lunar orbit insertion burn to capture into LLO while the LDN-1 satellite will control it lunar flyby state to target efficient re-rerendezvous with the Moon after transit to apogee of approximately 1.3 million km in solar orbit in order to leverage the solar gravity perturbation in a manner to reduces the delta-V required to insert into the target ELFO for PNT satellite constellation. Figure 1shows the LDN-1 lunar transfer trajectory.

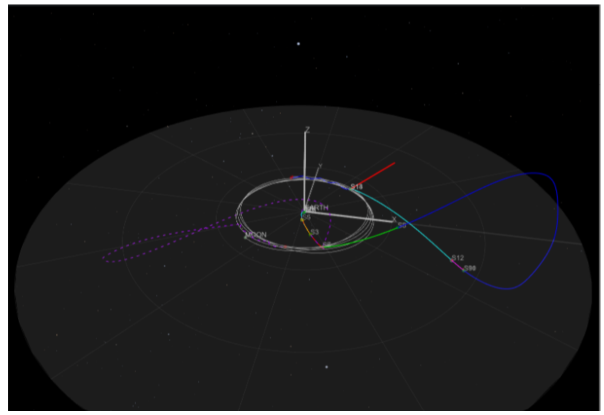

Figure 1: LDN-1 Lunar Transfer Trajectory

IM 5-Satellite Constellation Geometry. The initial IM LDN satellite geometry consists of five satellites in two orbit planes as shown in Figure 2. The orbital elements are optimized to provide coverage within 15 degrees latitude of the lunar South Pole in support of the NASA Artemis 3 and Artemis 4 missions.

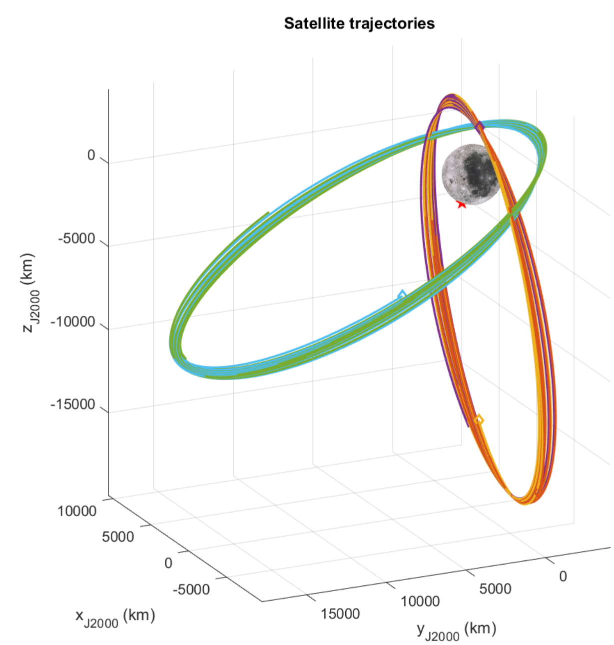

Figure 2: IM LDN Satellite Constellation Geometry

IM LDN User PNT Performance Capability. IM 5-Satellite Constellation Geometry. This signal in space errors from the IM LDN satellites are controlled to

13.43 meters and 1.2 mm/s 3-sigma per NASA requirement. Operating with this knowledge of the constellation position and velocity, then a forward broadcast signal is generated onboard each LDN spacecraft with a code-division multiple access (CDMA) signal specified by the Augment Forward Service (AFS) specification of the LNIS. The LDN constellation will also enable 2-way peer-to-peer tracking on S and Ka bands, as well as provide a data link with capability to transfer (1.6 Tbytes / day) per satellite to Earth for users on S, Ka, and X bands.

References: [1] P. Dafesh, J. Crenshaw, F. Melman, M. Murata (2025) *The Design of a Flexible, Interoperable Navigation Signal for Future Lunar Missions*, ITM 2025. [2] P. Giordano, R. Swinden, C. Grambling, J. Crenshaw, J. Ventura-Traveset (2023) *LunaNet Position, Navigation, and Timing Services and Signals, Enabling the Future of Lunar Exploration*, ITM 2023, 3577 - 3588.