***LUNAR VERTEX*: PRISM EXPLORATION OF REINER GAMMA.**

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Introduction: NASA designated Reiner Gamma (RG, Fig. 1) as the target for the first Payloads and Research Investigations on the Surface of the Moon (PRISM) delivery (dubbed PRISM-1a). Reiner Gamma is home to a magnetic anomaly, a region of magnetized crustal rocks. The RG magnetic anomaly is co-located with the type example of a class of irregular high-reflectance markings known as lunar swirls.

NASA's PRISM investigations are research and technology projects, not space-flight projects. The management requirements for PRISM are covered by NASA Procedural Requirements document NPR7120.8A. The NPR7120.8A requirements are much less stringent than those levied on space-flight projects, e.g., the Discovery program. The solicitation for the first two PRISM missions (1a and 1b, ROSES-2020 Appendix E.11) limited each mission's total payload to $30M and 50 kg.

PRISM payloads will be carried to the lunar surface on commercial landers as part of NASA's Commercial Lunar Payload Services (CLPS) program. The lander solicitation is issued after the selection of a PRISM investigation, with the PRISM payload accommodation requirements included as part of the "request for task order proposals" to which the CLPS companies respond.

The PRISM-1a lander and payload are designed for operation during one lunar daylight period. The lander will arrive at the surface shortly after local sunrise, and the mission will end near sundown.

APL's *Lunar Vertex* proposal was selected for the PRISM 1-a mission in June of 2021. The *Lunar Vertex* payload comprises three instruments hosted on the lander and a rover that carries two instruments. The Johns Hopkins University Applied Physics Laboratory is providing overall management of *Lunar Vertex*, systems engineering, safety and mission assurance, the two magnetometer instruments, and rover integration and testing.

***Lunar Vertex* Goals:** A lunar magnetic anomaly is a unique natural laboratory for addressing a wide range of questions that touch on planetary magnetism, lunar geology, space plasma physics, and space weathering [e.g., 1, 2]. *Lunar Vertex* will address all of these topics.

Lunar Vertex has the following goals: 1) Investigate the origin of lunar magnetic anomalies; 2) Investigate the origin of lunar swirls; 3) Determine the structure of the mini-magnetosphere that forms over the RG magnetic anomaly. In the course of pursuing those goals, the mission will provide key data in evaluating the importance of micrometeoroid bombardment vs. ion/electron exposure in the space weathering of silicate regolith. These goals are traceable to the Planetary Decadal Survey [3] and other NASA and community guiding documents [4-7].

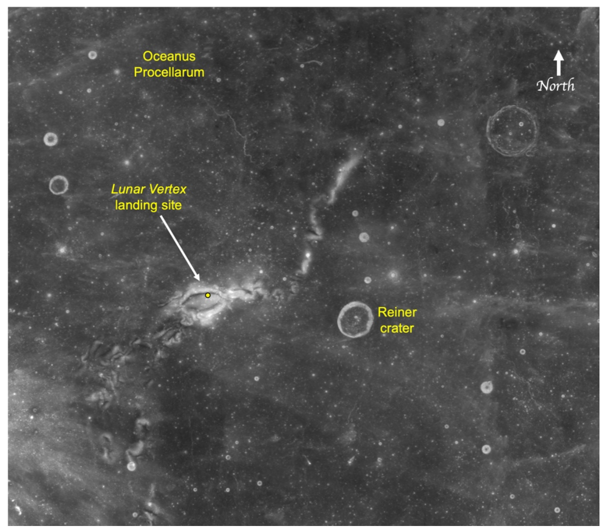

Fig. 1. RG is the sinuous bright marking. The landing site chosen by the *Lunar Vertex* team (7.585° N, 58.725° W) is marked with the dot. Reiner crater is ~30 km in diam.

Lander Instruments: The mission goals will be accomplished by payload elements on a lander and a rover. The lander suite includes:

The Vertex Camera Array (VCA) is a set of fixed-mounted cameras. VCA images will be used to (a) survey landing site geology, and (b) perform photometric modeling to yield information on regolith characteristics. VCA is being built by Redwire Aerospace of Littleton, Co. The VCA consists of three sets of three commercial, flight-qualified color camera clusters mounted on the lander. The three cameras in a set are arranged in a linear fan-beam configuration such that each camera's ~50° horizontal FOV overlaps, giving a full view of ~120°. The three camera sets are placed on the lander to provide ~360° view.

The Vector Magnetometer-Lander (VML) is a suite of fluxgate magnetometers. VML will operate during cruise and descent and once on the surface to measure the in-situ magnetic field at multiple altitudes and through varying upstream conditions. Sophisticated gradiometry employed by VML allows for separation of the natural field from that of the lander, and so enables accurate measurements of the magnetic field. Built by APL, VML has a small dual ring-core fluxgate sensor mounted at the end of a carbon-fiber mast, with low-noise cores and a full-scale range allowing for measurements of the small fields of the solar wind up to the large fields that may be present on the lunar surface at RG. VML also has four commercial Bartington Mag566 miniature magnetometers arrayed in a tetrahedron near the base of the mast.

The Magnetic Anomaly Plasma Spectrometer (MAPS) is a plasma analyzer that measures the energy, flux, and direction of ions and electrons that reach the surface. MAPS has heritage from the *Rosetta* Ion-Electron Spectrometer, and is provided by the Southwest Research Institute of San Antonio, Tx. The range of electron and ion energies is ~4 eV to 30 keV. The field of view is ~292° × 90°, with 5° × 5° angular resolution.

Rover. The lander will deploy the *Lunar Vertex* rover (Fig. 2), which conducts a traverse reaching ≥500 m distance, obtaining distributed measurements at locations outside the zone disturbed by the lander rocket exhaust (~30 m radius, estimated from the *Chang'e-3* lander [8]). Measurements of undisturbed regolith are key to testing hypotheses for the origin of swirls, and measurements of the magnetic field strength and direction along the traverse will help to determine the nature of the magnetic source.

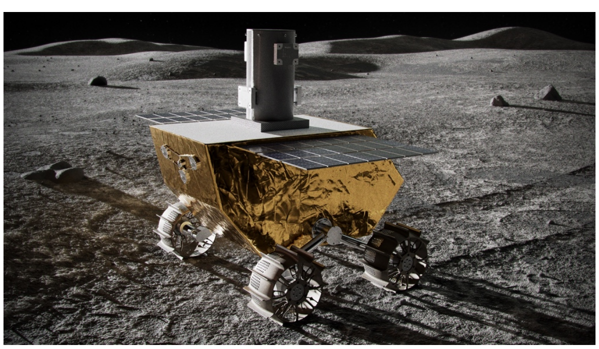

Fig. 2. Artist's drawing of the *Lunar Vertex* rover. The cylinder on the top is the VMR mast, shown without multilayer insulation wrap. Z-fold solar arrays are shown deployed. The rover is ~35 cm tall.

The *Lunar Vertex* rover is a version of the Lunar Outpost (Golden, Co.) Mobile Autonomous Prospecting Platform (MAPP). MAPP uses a hybrid computer-vision/LIDAR guidance, navigation, and control (GNC) system for autonomous navigation. The autonomy software allows a human operator to lay out waypoints, and MAPP operates to achieve the mission objectives.

Rover Instruments. The rover will carry two instruments. The APL Vector Magnetometer-Rover (VMR) is a copy of a portion of the lander magnetometer system: the tetrahedral array of Mag566 sensors on a short mast. VMR will assess variation in the strength and direction of the magnetic field as a function of position on the lunar surface, providing information on the nature of the magnetic source at RG, and hence helping to constrain models for the formation of lunar magnetic anomalies.

The Rover Multispectral Microscope (RMM) will collect images at wavelengths ~0.34–1.0 µm using active LED illumination. RMM is supplied by Canadensys Aerospace of Bolton, On., Canada. RMM will reveal the composition, texture, and particle-size distribution of the regolith beneath the rover, findings that will be compared with predictions of regolith character for the various hypotheses for formation of lunar swirls.

Mission Name: The mission's name adopts the Latin word "vertex", which can mean "swirl" or "whirlpool". The English word "vertex" invokes an intersection – here representing the crossroads of geoscience and the particles-and-fields domain of space physics. This intersection is the theme of the interdisciplinary *Lunar Vertex* mission.

Lander Selection. In November, 2021 NASA announced that Intuitive Machines of Houston, Tx. had been selected as the provider of the CLPS lander that will deliver *Lunar Vertex* to the Moon. In addition to *Lunar Vertex*, the lander will carry a high-energy particle detector (LUSEM) contributed by the Korea Astronomy and Space Science Institute in South Korea, the MoonLIGHT laser retroreflector from the European Space Agency, and a cooperative robotic technology demonstration (CADRE) led by the Jet Propulsion Laboratory and funded by the NASA Space Technology Mission Directorate. Launch is planned for April 2024.

References: [1] D. Blewett et al. (2021), *Bull. Am. Astron. Soc. 53*(4), DOI: 10.3847/25c2cfeb.9295af86. [2] https://science.nasa.gov/science-red/s3fs-public/atoms/files/Lunar INTREPID.pdf [3] NRC (2011), *Vision and Voyages for Planetary Science*, National Academies Press. [4] NRC (2007), *The Scientific Context for Exploration of the Moon*, National Academies Press. [5] SSERVI (2018), https://sservi.nasa.gov/articles/transformative-lunar-science/. [6] LEAG (2018), NEXT SAT report. [7] E. Jawin et al. (2019), *Earth Space Sci. 6*. DOI: 10.1029/2018EA000490. [8] R. Clegg-Watkins, et al. (2016), *Icarus 273*, 84–95.