Exploring a Lunar Magnetic Anomaly: The Lunar Vertex PRISM Mission

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Abstract

NASA designated Reiner Gamma (RG) as the landing site 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. RG is an ideal location to study how local magnetic fields change the interaction of an airless body with the solar wind, producing stand-off regions that are described as mini-magnetospheres. The Lunar Vertex mission, selected by NASA for PRISM-1a, has the following major goals: 1) Investigate the origin of lunar magnetic anomalies; 2) Determine the structure of the mini-magnetosphere that forms over the RG magnetic anomaly; 3) Investigate the origin of lunar swirls; and 4) Evaluate the importance of micrometeoroid bombardment vs. ion/electron exposure in the space weathering of silicate regolith. The mission goals will be accomplished by the following payload elements. The lander suite includes: The Vertex Camera Array (VCA), 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. The Vector Magnetometer-Lander (VML) is a fluxgate magnetometer. VML will operate during descent and once on the surface to measure the in-situ magnetic field. Sophisticated gradiometry allows for separation of the natural field from that of the lander. The Magnetic Anomaly Plasma Spectrometer (MAPS) is a plasma analyzer that measures the energy, flux, and direction of ions and electrons. The lander will deploy a rover that conducts a traverse reaching [?]500 m distance, obtaining spatially distributed measurements at locations outside the zone

disturbed by the lander rocket exhaust. The rover will carry two instruments: The Vector Magnetometer-Rover (VMR) is an array of miniature COTS magnetometers to measure the surface field. The Rover Multispectral Microscope (RMM) will collect images in the wavelength range ˜0.34–1.0 um. RMM will reveal the composition, texture, and particle-size distribution of the regolith.

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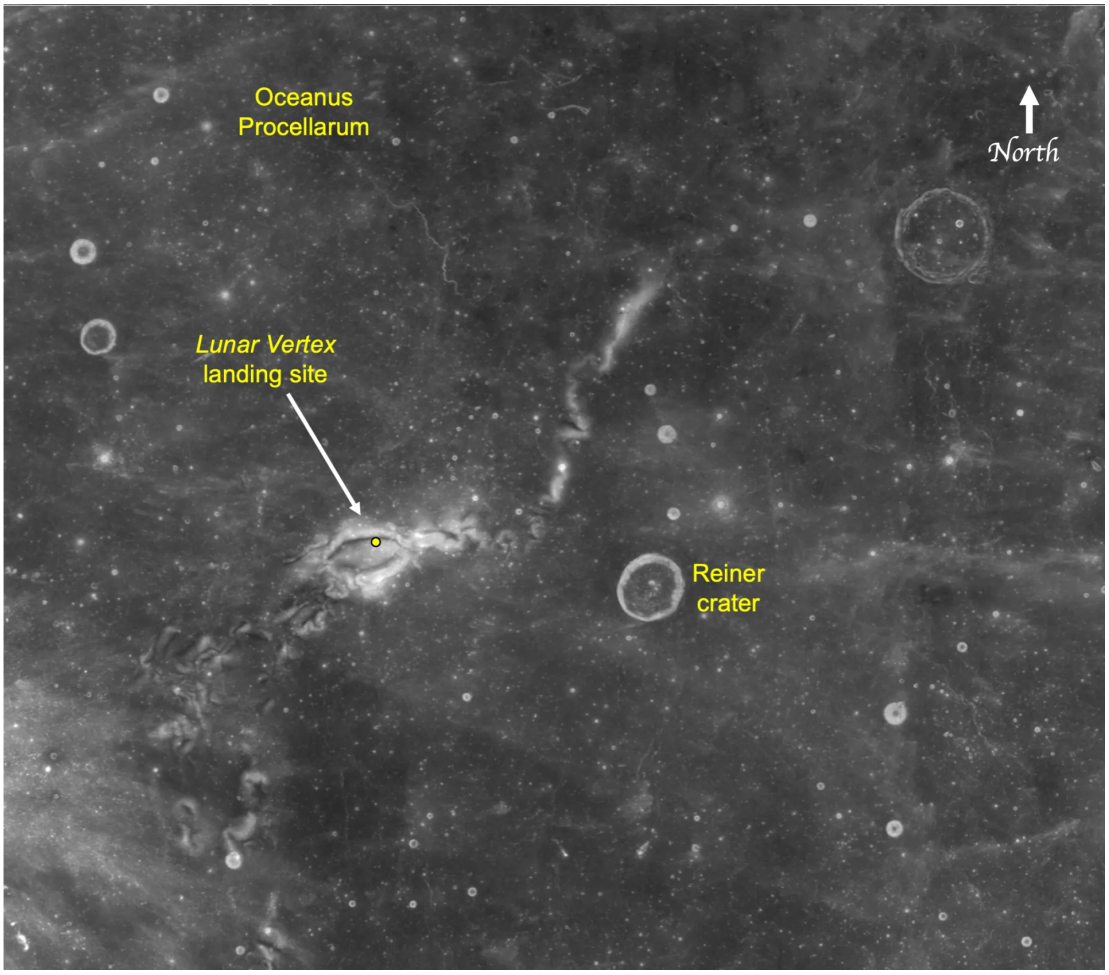
1. PRISM & REINER GAMMA

NASA designated Reiner Gamma (RG) as the landing site 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 Reiner Gamma magnetic anomaly is co-located with the type example of a class of irregular high-reflectance markings known as lunar swirls.

PRISM payloads will be ferried 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.

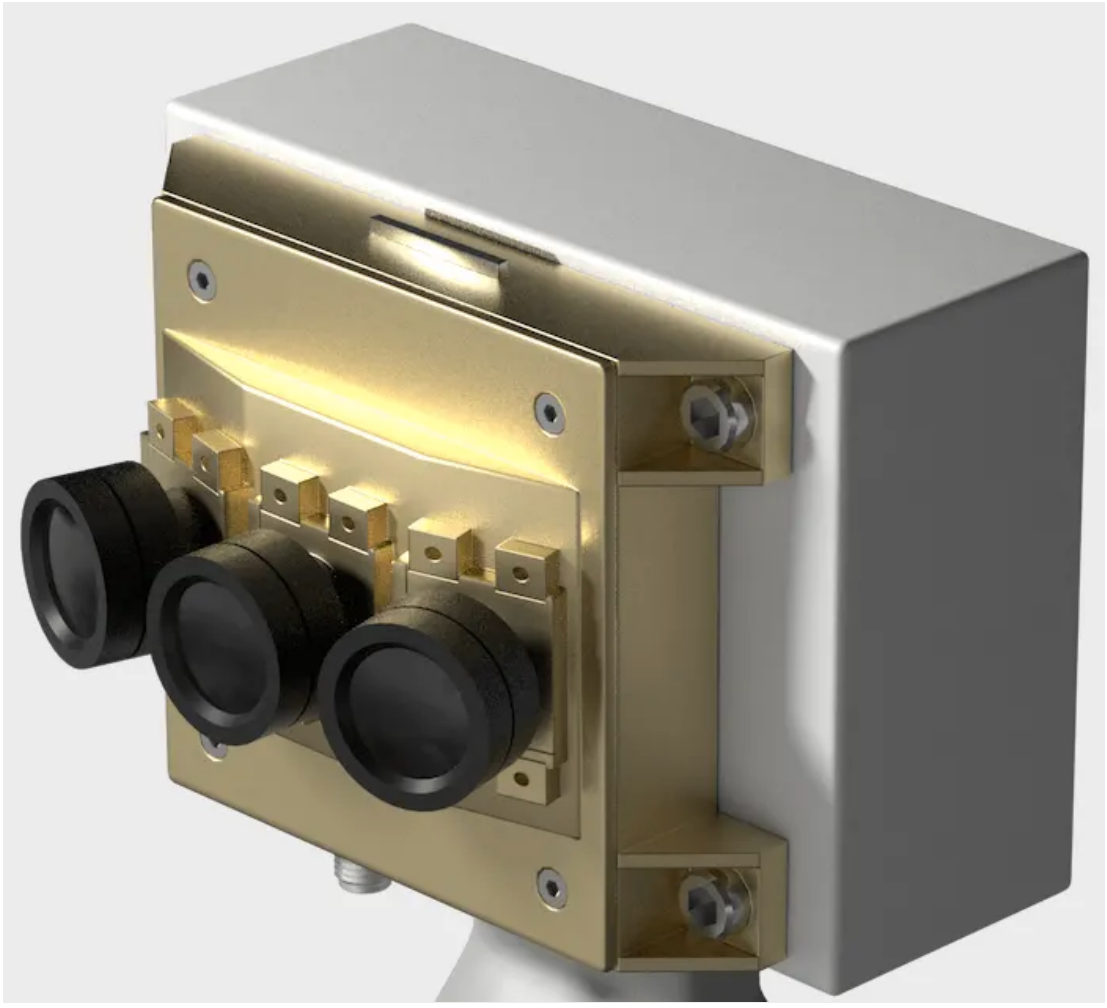


Reiner Gamma is the sinuous bright marking. The *Lunar Vertex* landing site (7.585° N, 58.725° W) is marked with the dot. Reiner crater is ~30 km in diameter.

3. LANDER INSTRUMENTS

The mission goals will be accomplished by the following payload elements. The lander suite includes:

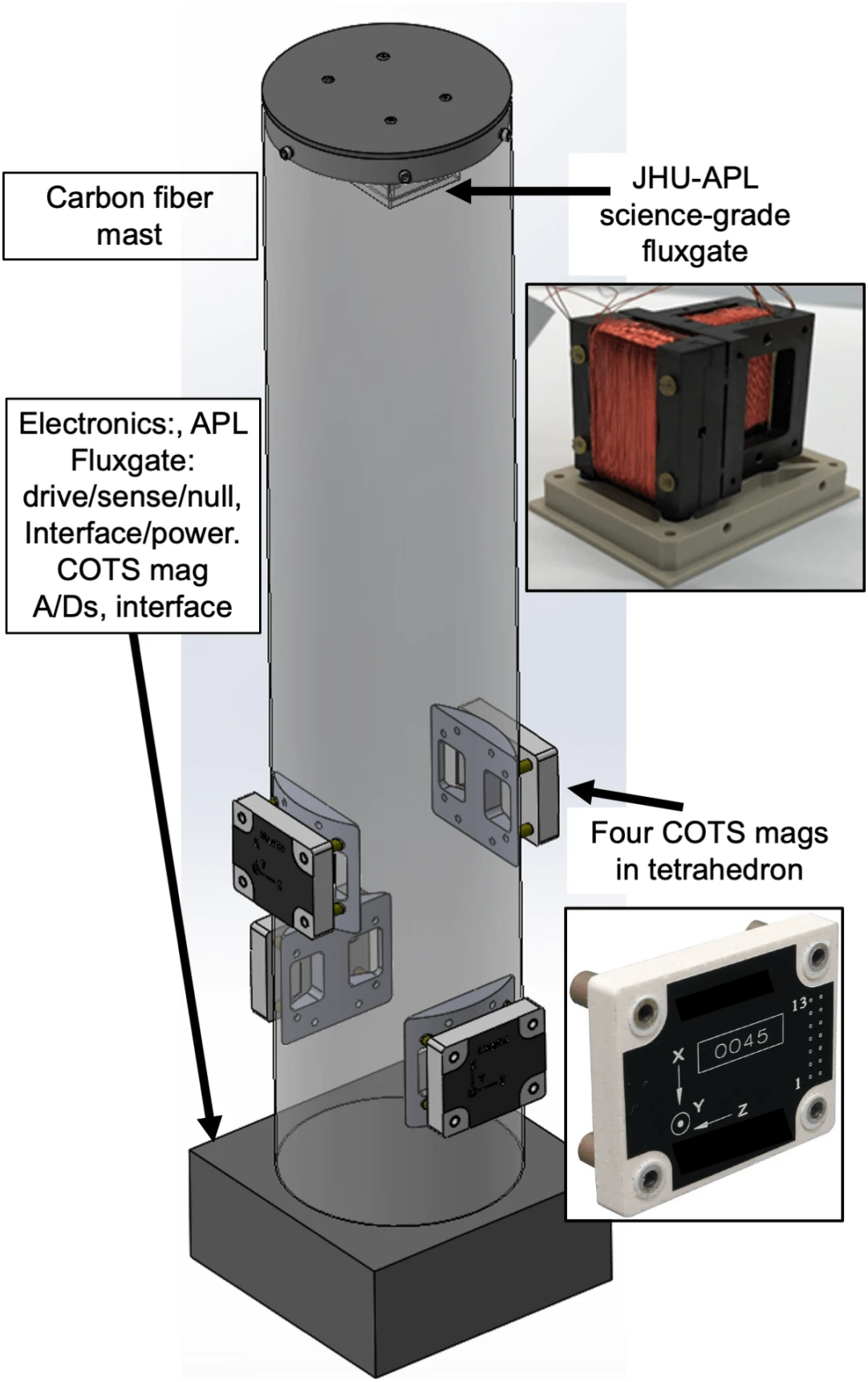
The Vertex Camera Array (VCA), a set of fixed-mounted cameras. VCA images will be used to (a) survey landing site geology, and (b) perform photometric modeling to yield information on regolith characteristics. VCA is being built by Redwire Aerospace of Littleton, Co. The VCA consists of three sets of 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.



A VCA camera cluster.

The Vector Magnetometer-Lander (VML) is a fluxgate magnetometer. VML will operate during descent and once on the surface to measure the in-situ magnetic field. Sophisticated gradiometry allows for

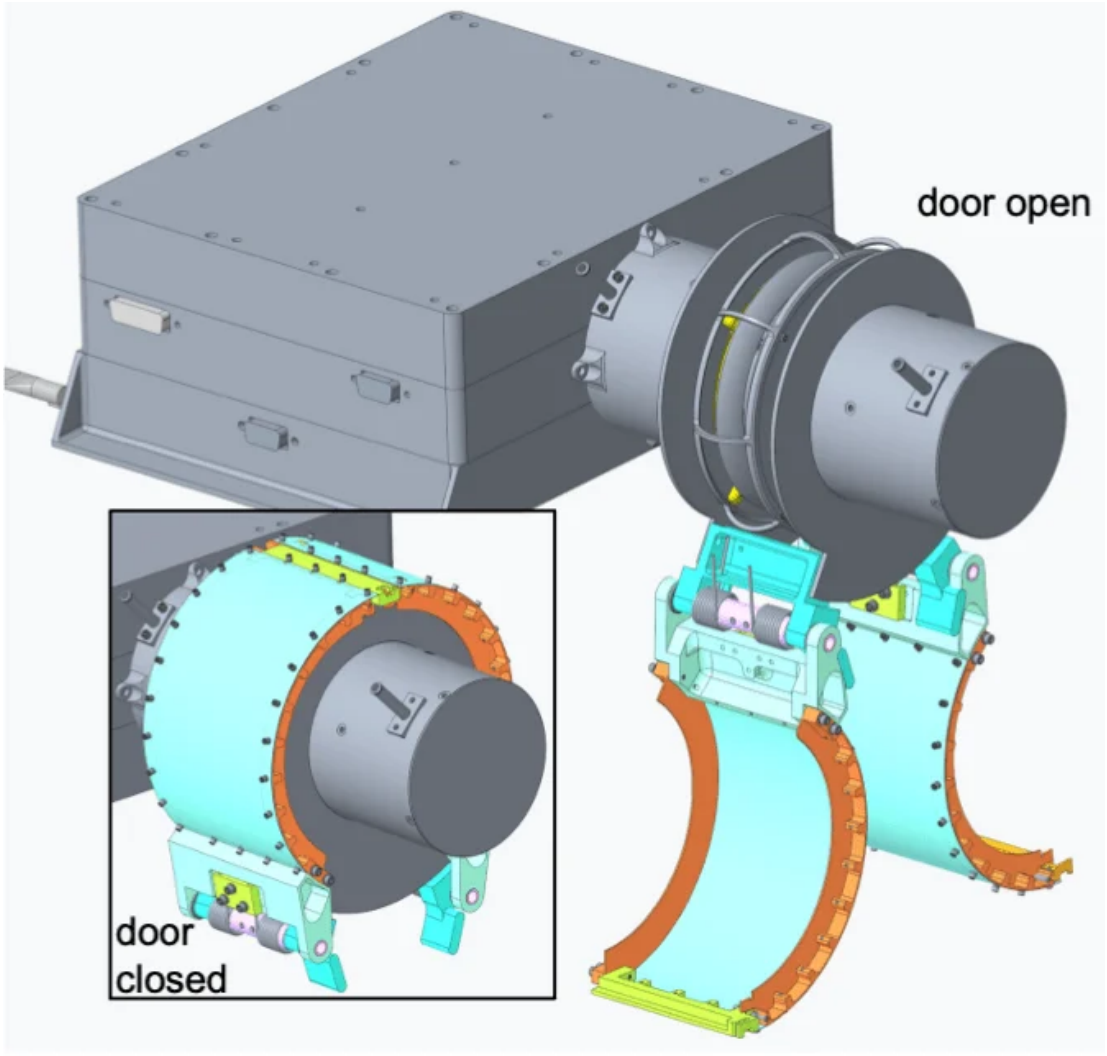
separation of the natural field from that of the lander. JHU-APL is building VML. VML is a small dual ring-core fluxgate sensor mounted at the end of a carbon-fiber mast, with four COTS Bartington Mag566 miniature magnetometers arrayed in a tetrahedron near the base of the mast. The fluxgate has a digitization resolution of 0.12 nT and can measure magnetic fields with magnitudes as low as 0.12 nT, allowing the resolution of small fields. The fluxgate and the Mag566 vector outputs are obtained with full scales of ±65,000 nT and ±100,000 nT, respectively, all with 20-bit resolution, at rates of ten samples/sec.



The VML. The mast is ~50 cm tall.

The Magnetic Anomaly Plasma Spectrometer (MAPS) is a plasma

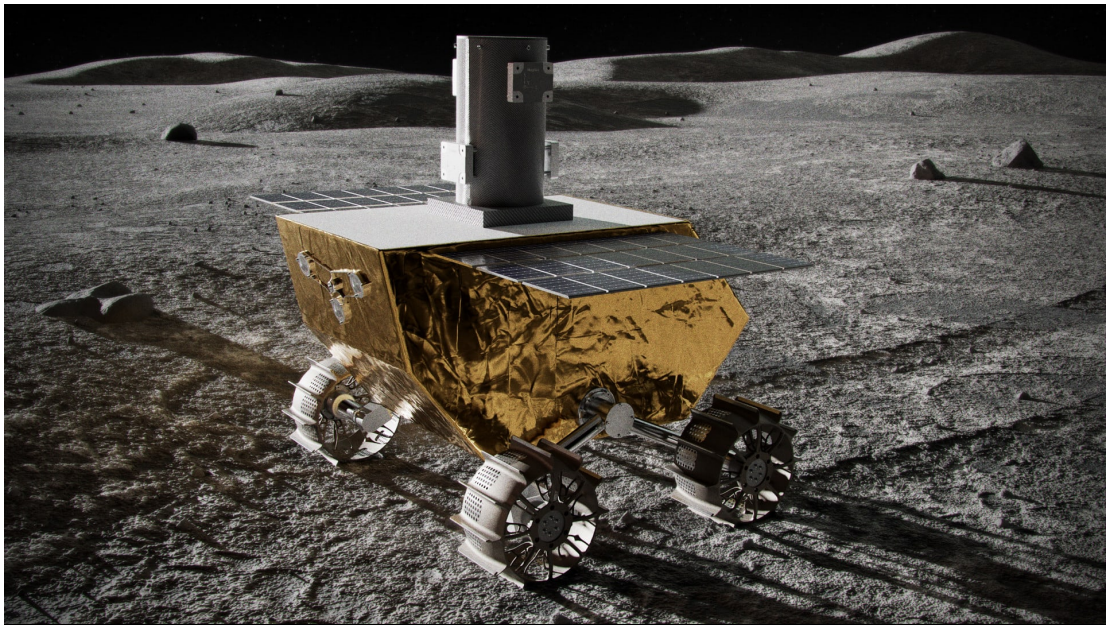
analyzer that measures the energy, flux, and direction of ions and electrons that reach the surface. MAPS has heritage from the *Rosetta* Ion-Electron Spectrometer, and is supplied by the Southwest Research Institute. The range of electron and ion energies is ~4 eV to 30 keV. The field of view is ~292° x 90°, with 5° x 5° angular resolution.



The MAPS instrument. The door protects the instrument high-voltage components from dust and will be opened after landing.

4. ROVER

The lander will deploy a rover that conducts a traverse reaching ≥500 m distance, obtaining spatially distributed measurements at locations outside the zone disturbed by the lander rocket exhaust. Measurements of undisturbed regolith are key to testing hypotheses for the origin of swirls.



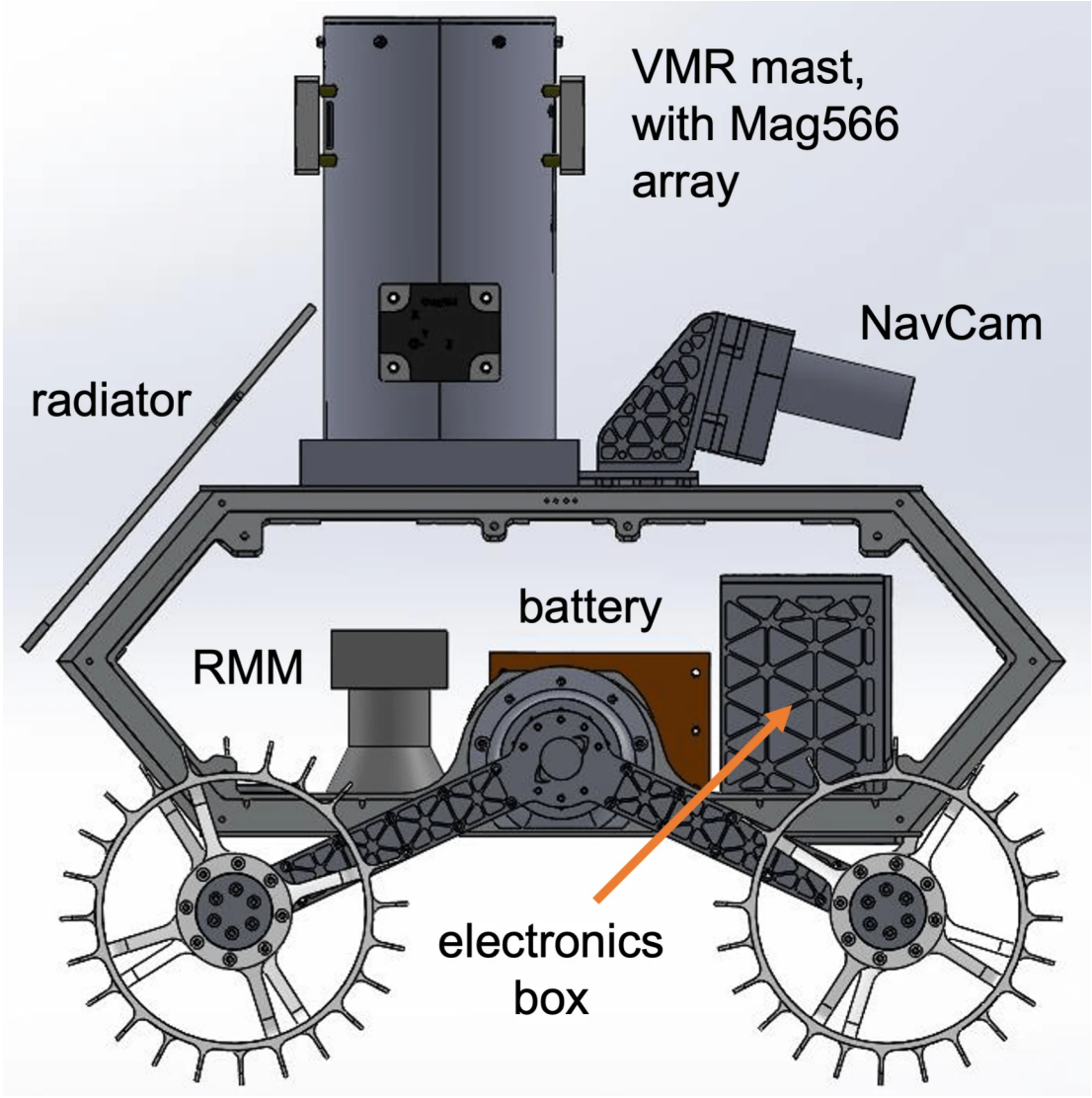
Artist's drawing of the rover. The cylinder on the top is the magnetometer array, shown without multilayer insulation wrap. The rover is ~35 cm tall.

The rover is a version of the Mobile Autonomous Prospecting Platform (MAPP), and is provided by Lunar Outpost of Golden, Co. 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. Communications with the lander will be via S- or X-band radio.

5. ROVER INSTRUMENTS

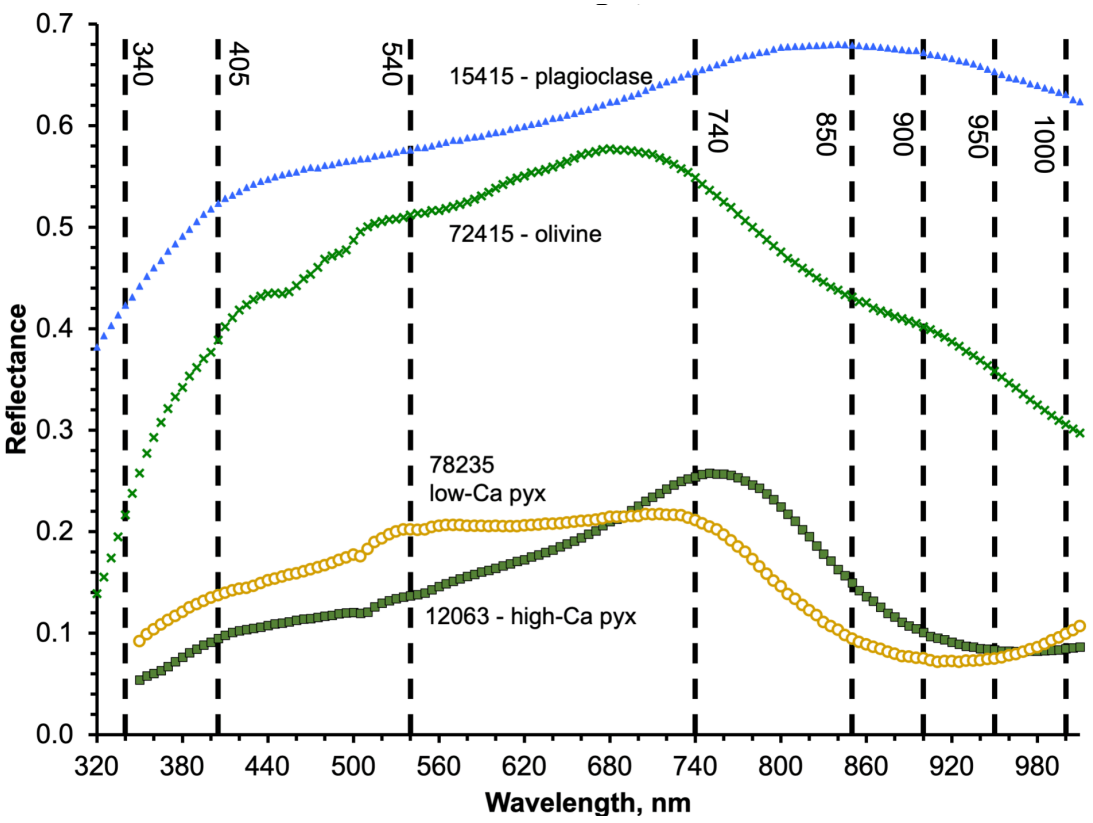
The rover will carry two instruments.

The Vector Magnetometer-Rover (VMR) is a copy of a portion of the lander magnetometer system: the tetrahedral array of Mag566 sensors. VMR has a short mast and a one-board electronics box for the Mag566 analog-to-digital converter (ADC) and to interface to the rover. APL will build VMR. VMR will assess variation in the strength and direction of the magnetic field as a function of position will provide information on the nature of the magnetic source, and hence help to constrain models for the formation of lunar magnetic anomalies.

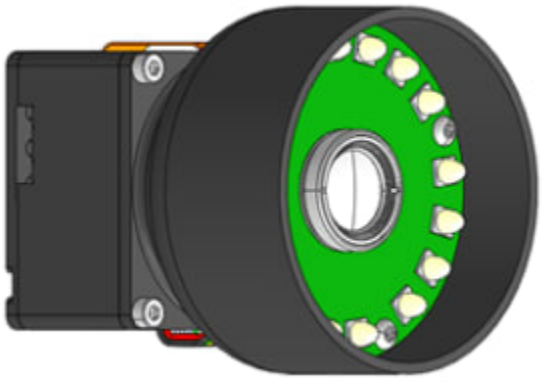


The Rover Multispectral Microscope (RMM) will collect images in the wavelength range ~0.34–1.0 μm using active LED illumination. RMM is supplied by Canadensys Aerospace. RMM will reveal the composition, texture, and particle-size distribution of the regolith beneath the rover,

findings which will be compared with predictions of regolith character for the various hypotheses for formation of lunar swirls.



Reflectance spectra of major lunar minerals, with vertical lines showing the RMM LED wavelengths.



CAD model of the RMM camera, showing the ring of LEDs that provide multispectral illumination.

2. 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. APL's *Lunar Vertex* mission, competitively selected by NASA for PRISM-1a in June of 2021, will address all of these topics.

Lunar Vertex has the following major goals: 1) Investigate the origin of lunar magnetic anomalies; 2) Determine the structure of the mini-magnetosphere that forms over the RG magnetic anomaly; 3) Investigate the origin of lunar swirls; and 4) Evaluate 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 and other NASA and community guiding documents.

APL is providing overall management, systems engineering, safety and mission assurance, the two magnetometer instruments, and rover integration and testing.

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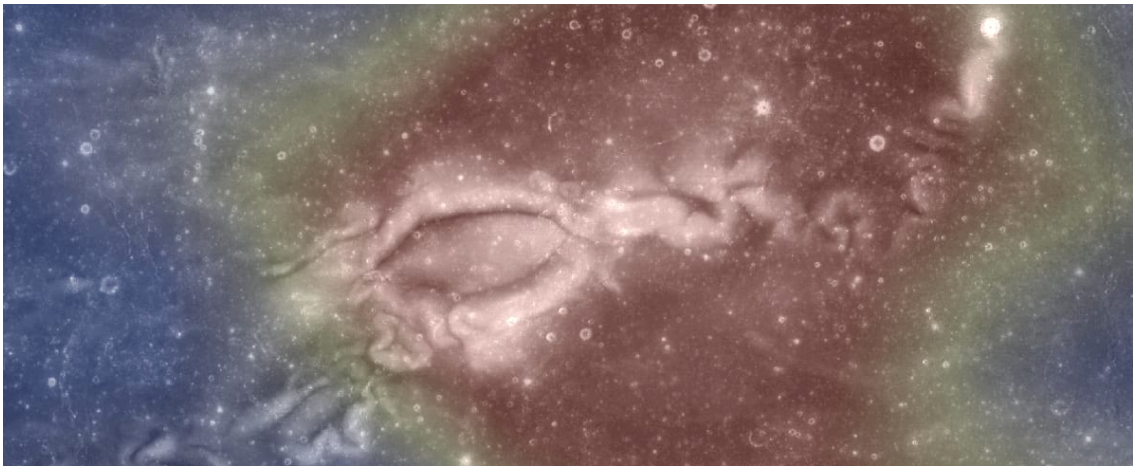

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6. LANDER SELECTION

On November 17, 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) supplied by the Korea Astronomy and Space Science Institute (KASI) 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.

Artist's rendering of the Intutive Machines lander.

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