SELECTION AND CHARACTERIZATION OF THE LANDING SITE FOR NASA CLPS PRISM1 LUNAR LANDER MISSION CP-11.

David T. Blewett[1,*], Heather M. Meyer[1], Mallory J. Kinczyk[1], Jasper Halekas[2], George C. Ho[1], Benjamin T. Greenhagen[1], Brett W. Denevi[1], Rachel L. Klima[1], Joshua T.S. Cahill[1], Brian J. Anderson[1], Sarah K. Vines[1], C. Dany Waller[1], Leonardo Regoli[1], Jörg-Micha Jahn[3], Peter Kollmann[1], Lon L. Hood[4], Sonia Tikoo[5], Xiao-Duan Zou (邹小端)[6], Mark Wieczorek[7], Myriam Lemelin[8], Shahab Fatemi[9], Edward A. Cloutis[10], Heidi Haviland[11], Ryan Watkins[12], Scott Moreland[13], Adriana Daca[13], Subha Comandur[13]. [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [2]Univ. of Iowa, Iowa City, IA. [3]Southwest Research Inst., San Antonio, TX. [4]Univ. of Arizona, Tucson, AZ. [5]Stanford Univ., Stanford, CA. [6]Planetary Science Inst., Tucson, AZ. [7]Obs. de la Cote d'Azur, France. [8]Univ. de Sherbrooke, QC, Canada. [9]Umea Univ., Sweden. [10]Univ. of Winnipeg, Winnipeg, MB, Canada. [11]NASA MSFC, Huntsville, AL. [12]NASA HQ, Washington, DC. [13]Jet Propulsion Lab, Pasadena, CA. (*david.blewett@jhuapl.edu).

Introduction: The NASA Commercial Lunar Payload Services (CLPS) program delivery known as "CP-11" will carry multiple payloads to the lunar surface in 2024. The payloads include (a) *Lunar Vertex*, the first science suite sponsored by the NASA Science Mission Directorate's Payloads and Research Investigations on the Surface of the Moon (PRISM) program, (b) JPL's CADRE (Cooperative Autonomous Distributed Robotic Explorers), a project from the NASA Space Technology Mission Directorate's Game Changing Development Program, (c) the Lunar Space Environment Monitor (LUSEM), a high-energy particle detector from the Korea Astronomy and Space Science Institute (KASI) and funded by the Ministry of Science and ICT of Korea (MSIT), and (d) MPAc (MoonLIGHT Pointing Actuator), a laser retro-reflector developed by the National Institute for Nuclear Physics (INFN-LNF) and funded by the European Space Agency.

The general landing location for the CP-11 delivery was chosen by NASA: Reiner Gamma (RG) in Oceanus Procellarum on the Moon's nearside. Proposals to the competitive PRISM1 solicitation were evaluated on how well they addressed specific science goals that could be carried out at RG. The *Lunar Vertex* investigation, led by the Johns Hopkins University Applied Physics Lab, was selected by NASA for the RG PRISM1 opportunity. After selection of *Lunar Vertex*, the CLPS office issued a Request for Task-Order Proposals (RFTOP) to the CLPS vendor pool. The RFTOP included requirements for accommodation of the *Lunar Vertex*, CADRE, LUSEM, and MPAc payloads. Intuitive Machines (IM) was selected to provide the lander service for CP-11; this is IM's third CLPS contract for their Nova-C lander.

The selection of the landing site was primarily driven by the *Lunar Vertex* payload needs and the specific site was proposed by the *Lunar Vertex* science team. The *Lunar Vertex* and CADRE rovers have largely similar terrain and environmental constraints, while the LUSEM and MPAc payloads did not have needs that influenced site selection. In this abstract, we discuss the science and operational considerations that went into choice of the landing site and provide information on the site's physical characteristics.

Science Background: RG is a natural laboratory for addressing a wide range of questions that touch on planetary magnetism, lunar geology, space plasma physics, and space weathering. RG corresponds to a region of magnetized crustal rocks (known as a magnetic anomaly). Several hypotheses for the origin of lunar magnetic anomalies have been proposed (summarized in [1]), including remnant magnetism from an ancient lunar dynamo and magnetism caused by plasma effects related to ejecta from basin-forming impacts or by the impact of a comet.

Co-located with the RG magnetic anomaly is the most famous example of a lunar swirl. A sinuous, high-reflectance surface marking, the RG swirl exhibits no topography in available data. The origin of swirls is a long-standing puzzle. Hypotheses for the formation of swirls (summarized in [1]) include magnetic shielding of the surface from the darkening effects of the solar wind, scouring by gas and dust during the collision of a comet's coma or a meteoroid swarm, and accumulation of fine-grained dust in response to magnetic or electric fields associated with the magnetic anomaly.

The presence of the magnetic anomaly at RG causes interactions with the solar wind that lead to interesting plasma physics phenomena. For example, data from orbital spacecraft have demonstrated that mini-magnetosphere stand-off regions exist above the Moon's strongest magnetic anomalies (*cf.* [1]).

The *Lunar Vertex* payload was designed to address three science goals [2]: (1) test hypotheses for the origin of the RG magnetic anomaly, (2) test hypotheses for the origin of the RG swirl, and (3) determine the structure of the RG mini-magnetosphere. The payload suite consists of three instruments on the lander (an ion-electron spectrometer, an array of RGB cameras, and a magnetometer array), and two instruments on a small commercial rover (a magnetometer array and a multispectral microscope).

Landing Site Selection: The first-order *Lunar Vertex* science considerations for the landing site were to visit an area of high magnetic field strength as determined from orbital maps, and to choose a location that would allow the rover to examine the soil both in a bright swirl region and in an area representing a dark lane or the non-swirl background. Determination of the rover traverse distance required to accomplish the science goals was made based on (a) the need to travel beyond the area of the lander's rocket exhaust disturbance, (b) the need to examine how the regolith texture, composition, and optical maturity vary as a function of location and to document the associated magnetic field, and (c) the distance scale necessary to distinguish among various models for the nature of the magnetic source. A baseline traverse distance of 500 m met these criteria, although the rover's range during the 13 Earth-day mission is expected to be ~1.2 km.

Operational constraints. Lander safety necessitates a location that is free of steep slopes and abundant boulders. Fortunately, the mare surface at RG is generally smooth and level. RG was a Constellation target of interest, and hence excellent high-resolution LROC-NAC images and NAC-based topographic maps are available. The best NAC coverage (2 m/pix) is for an area along the eastern part of the central RG bright oval. In addition, we consulted data products such as LRO Diviner rock abundance and night-time temperature maps [3] and *Kaguya* MI spectral maps [4] in order to narrow the areas for consideration. Viewshed maps derived from NAC topography with assumed lander radio antenna heights of 1, 2, and 3 m revealed many potential paths for the rover to make a traverse of the desired distance north toward the dark lane while maintaining line-of-sight to the lander. The location selected is at 7.585° N, 58.725° W (Fig. 1).

Additional Site Characterization: Following the designation of the landing site, the CADRE project undertook an evaluation of the location as an aid to engineering and operation of their rovers [5]. This effort documented topographic slopes and slope distribution, estimated the abundance and size-frequency distribution of rocks and craters, and examined regolith mechanical properties.

References: [1] D.T. Blewett et al. (2021), *B.A.A.S. 53*(4), DOI: 10.3847/25c2cfeb.9295af86. [2] D.T. Blewett et al. (2022), *LPSC 53rd*, abstr. 1131. [3] J.L. Bandfield et al. (2011), *JGR 116*, E00H02. [4] M. Lemelin et al. (2019), *PSS 165*, 230. [5] A. Daca and S. Moreland (2022), *Terrain Specifications-CADRE Lunar Rover Project*, JPL internal document.

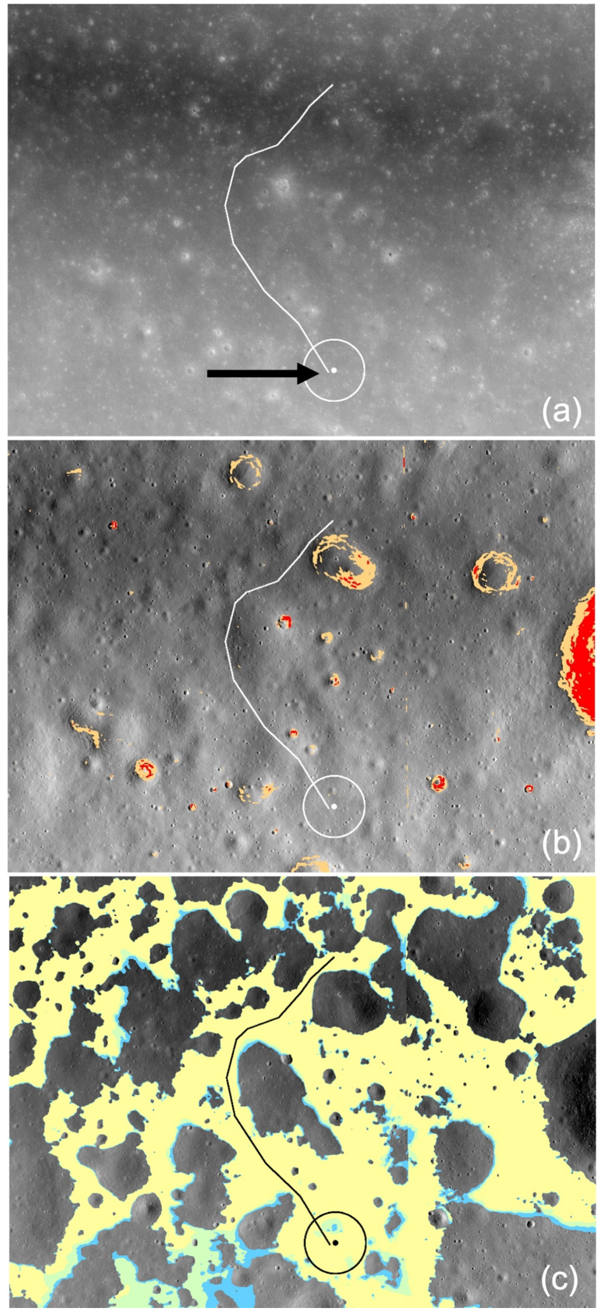

Fig. 1. Maps of the CP-11 landing site. (a) NAC high-Sun controlled mosaic showing the bright portion of the RG swirl and the dark lane to the north. The landing site is the white dot indicated by the black arrow. Scale is indicated by the 200-m diameter circle. (b) NAC image with slopes >10° in orange, >15° in red. (c) Viewshed for lander antenna heights of 1 m (yellow), 2 m (green), and 3 m (blue). A preliminary *Lunar Vertex* rover traverse path of ~1.2 km is shown on each map.