S.P. HOPPER: IN-SITU EXPLORATION OF THE SHACKLETON DE GERLACHE RIDGE.

T.D. Martin[1], M.J. Atwell[1], D.B.J. Bussey[1], N.M. Estes[2], M. Grott[3], M. Hamm[3,4], J. Knollenberg[3], C.E. Miconi[2], T. Pacher[5], M.S. Robinson[2], E.J. Speyerer[2]. R.V. Wagner[2]; [1]Intuitive Machines, Houston, TX (trent@intuitivemachines.com), [2]Arizona State University, Tempe, AZ, USA, [3]German Aerospace Center (DLR), Berlin, Germany, [4]Free University Berlin, Germany, [5]Puli Space Technologies, Budapest, Hungary.

Introduction: A deployable robotic hopper enables exploration of challenging terrains not easily accessible to rovers: permanently shadowed regions, rough or blocky targets, pits, and steep slopes [**1,2,3**]. The µNova hopper [**1**], developed by Intuitive Machines (IM), was designed for these exploration challenges.

As part of the IM-2 mission (a NASA CLPS delivery) an IM Nova-C lander will deliver the first µNova hopper to a landing site near the south pole. The Nova-C will also deliver the Polar Resources Ice Mining Experiment-1 (PRIME-1) consisting of The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) and the Mass Spectrometer observing lunar operations (MSolo) [**4**] as well as a Lunar Outpost rover carrying a NOKIA demonstration LTE communication system [**5**].

µNova System Description: The µNova hopper is 70 cm tall and has a total system mass of 35 kg. The hopper is a fully independent spacecraft with propulsion, avionics, power, flight controls, and communication systems. The hopper utilizes a precision landing and hazard avoidance (PLHA) system that images the surface and autonomously guides the vehicle to a safe landing site. The hopper will communicate with the Nova-C through an LTE system enabling contact when out of sight.

As its name implies, this first µNova, named South Pole Hopper, or S.P. Hopper, will explore a region near the south pole. S.P. Hopper will carry science cameras, the Lunar Radiometer (LRAD) [**6**], and the Puli Lunar Water Snooper (PLWS) [**7**]. S.P. Hopper demonstrates the µNova technology, but it also has significant scientific objectives that will be fulfilled after completing the required flight objectives. 1) Geologic context and geotechnical properties for a portion of the Shackleton – de Gerlache ridge, including within a PSR. 2) Determination of surface brightness temperatures in the illuminated and shadowed terrain. 3) Derive the surface roughness and thermal inertia of illuminated polar regolith. 4) Determine hydrogen (H) abundance in illuminated regions and within a PSR.

Cameras: The imaging experiment consists of two Canadensys [**8**] CMOS imaging systems: Medium Angle (MA) monochrome 51° × 39° field-of-view (FOV) and Wide Angle (WA) monochrome 144° × 104° FOV. While in flight, the two cameras will acquire continuous stereo observations.

LRAD: LRAD will provide the first in-situ measurement of the brightness temperatures within a PSR. Thermopile sensors measure the net radiative flux in the thermal infrared wavelength range [**9**]. The sensor head carries six thermopile sensors with individual IR filters to fulfill its measurement objectives. The instrument design is based on the miniRAD radiometer of the Martian Moons Explorer (MMX) rover [**10**]. The main challenge for precise temperature measurement is the low flux emitted by the surface at the predicted temperatures, so the LRAD sensor head temperature is stabilized to the mK level. A closed sensor measures residual disturbances caused by self-radiation.

PLWS: PLWS is a miniaturized (10×10×3.4 cm), simple and lightweight (<400 gr), low-cost, commercial off-the-shelf, neutron spectrometer. It detects incoming cosmic rays (CR) and neutron particles emitted from the regolith in the thermal and epithermal range.

PLWS consists of three modified CMOS active pixel image sensors as detectors: a Thermal Neutron (TH), an Epithermal Neutron (EPI), and a Reference Sensor), as well as an FPGA. The TH and EPI CMOS have a thin neutron-sensitive coating. Neutron capture within the coating generates alpha and Li ions, which cause ionization tracks in the sensor. In front of the EPI sensor, a thin Gadolinium filter absorbs the thermal neutrons, enabling energy-selective neutron detection. The Reference Sensor collects background CR information for calibrating the TH and EPI counts. PLWS is sensitive to H abundance detection down to 0.3% WEH (water equivalent hydrogen).

S.P. Hopper ConOps: Within 24 hours of the Nova-C landing on the Shackleton – de Gerlache ridge (~89.49°S, 222.1°E), S.P. Hopper will execute a 20-m commissioning hop. It will then demonstrate its required capabilities with a 100-m test flight. Next, a long hop (>300 meters) will position the vehicle on the rim of Marston crater (89.48°S, 222.9°E). This hop will also demonstrate the capability to traverse at a constant altitude. Next, S.P. Hopper will fly into and land within the PSR and remain on the PSR floor for ~45 minutes collecting images, radiometer, and neutron observations. Finally, S.P. Hopper will fly up and out of Marston crater, landing again on the rim. If enough fuel is remaining, a sixth flight may be undertaken.

References: [**1**] Atwell et al. (2020) LSSW, Abstract #6011. [**2**] Robinson et al., LSSW 2021 #8034, (2021). [**3**] Martin et al., ELS. pp. 137-138 (2022). [**4**] https://tinyurl.com/2s3ehkhu [**5**] https://tinyurl.com/uejwvsch [**6**]] Hamm, M., et al., (2022), 53rd LPSC, #1393 [**7**] Pacher, T., et al. (2022) Abs. #39, Lunar Surf. Innovation Consor. Fall Meeting [**8**] https://www.canadensys.com/ [**9**] Grott, M., et al., (2017). Space Sci Rev., 208, 413 [**10**] Ulamec, S., et al., (2021). 72nd IAC, IAC-21-A3.4A.7