S.P. HOPPER: IN-SITU EXPLORATION OF THE SHACKLETON DE GERLACHE RIDGE. T. Martin[1], M. 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], R.V. Wagner[2]; [1]Intuitive Machines (13467 Columbia Shuttle St., Houston, TX 77059, 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: permanently shadowed regions (PSR), rough or blocky targets, pits, and steep slopes [**1,2,3**]. The µNova hopper [**1**], developed by Intuitive Machines (IM), was specifically designed to meet such exploration challenges.

The first demonstration of the µNova hopper is scheduled for late 2024. The IM-2 mission will see an IM Nova-C lander deliver the µNova hopper to a landing site near the south pole as part of the NASA Commercial Payload Services (CLPS) program. 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 demonstration LTE communication system [**5**].

µNova System Description: The µNova hopper is 70-cm tall and has a total system mass of 35-kg (**Fig. 1**). 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. Landing on slopes up to 10° can be achieved, along with landing in low-light environments such as PSRs or pits. The hopper will communicate with the Nova-C through an LTE system enabling contact when out-of-sight with the lander.

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 is a demonstration of the µNova technology but it also has significant scientific objectives that will be fulfilled after completing the required flight objectives.

Objective 1: Geologic context and geotechnical properties for a portion of the Shackleton – de Gerlache ridge, including within a PSR.

Objective 2: Determination of surface brightness temperatures in the illuminated and shadowed terrain.

Objective 3: Derive the surface roughness and thermal inertia of illuminated polar regolith.

Objective 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 inflight the two cameras will acquire continuous stereo observations. The MA is pointed nadir and maps a swath 120 meters wide (cross-track) with a pixel scale of 3 cm along the flight path enabling a digital terrain model (DTM) with 10-cm posting. The WA boresight is aimed 45° from nadir aligned 10° from the line of flight with a center pixel scale of 12 cm from 100 meter altitude A 4-color LED lighting panel allows mm pixel scale near-field color imaging with the WA system while S.P. Hopper is on the surface within the PSR.

Fig. 1. View of S.P. Hopper looking down line-of-flight.

LRAD: 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 objections (**Fig. 1**). The instrument design is based on the miniRAD radiometer of the Martian Moons Explorer's (MMX) rover [**10**].

LRAD will provide the first in-situ measurement of the brightness temperatures within a PSR. The main challenge for precise temperature measurement is the low flux emitted by the surface for the predicted temperatures, which could be below 100 K [10]. To this end, the LRAD sensor head temperature is stabilized to the mK level, minimizing disturbances from instrument self-radiation. A closed sensor will help to estimate residual disturbances caused by self-radiation. Furthermore, the instrument is thermally decoupled from the environment as much as possible. A large field of view of 40° (FWHM) maximizes the collected signal. LRAD uses two long-pass filters opening at a wavelength of 15µm and designed to measure low temperatures independently, allowing for a precise uncertainty estimate. A long-pass filter opening at 10µm enables measurements of the higher temperatures outside the PSRs.

PLWS: PLWS is a miniature, lightweight neutron spectrometer for lunar applications (**Fig. 2**). It detects incoming cosmic rays (CR) and neutron particles emitted from the regolith in the thermal and epithermal range. PLWS is a miniaturized (10 cm × 10 cm × 3.4 cm), simple and lightweight (<400 gr), low-cost, COTS (Commercial off-the-shelf) based system.

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 a 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 also utilizes a Gadolinium Ballistic Shield above the CMOS sensors to mitigate the effect of the lunar ballistic thermal neutrons that originate outside measurement area. Monte Carlo simulations indicate that several hours of integration at stationary locations results in ~1,000 thermal and epithermal neutron counts, allowing H abundance detection down to 0.3% WEH (water equivalent hydrogen).

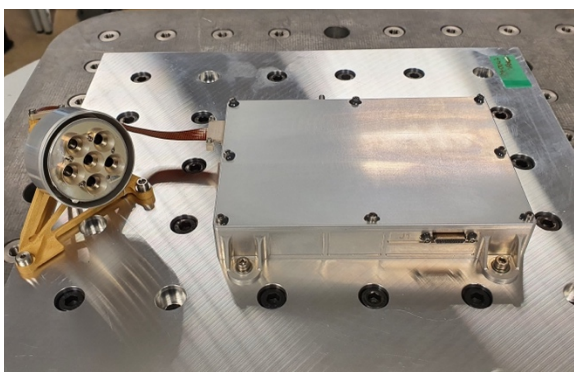

Fig. 2. LRAD undergoing vibrational testing with sensor head mounted on a thermally isolating bracket (left), and the avionics box (right.)

S.P. Hopper ConOPS: Within 24 hours of the Nova-C landing on the Shackleton – de Gerlache connecting ridge (~89.49°S, 222.1°E), S.P. Hopper will execute a commissioning hop of 20 meters. Cameras onboard the Nova-C will record the flight, as will S.P. Hopper cameras. After commissioning hop images and housekeeping data are analyzed, S.P. Hopper will demonstrate its required capabilities with a 100-meter test flight. After another period of data analysis, a long hop (>300 meters) will position the vehicle on the rim of Marston crater (informal name; 89.48°S, 222.9°E). Next, S.P. Hopper will fly into and land within the Marston PSR. The vehicle will 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. At that time, S.P. Hopper will collect more scientific observations, and if enough fuel is remaining, a sixth flight may be undertaken.

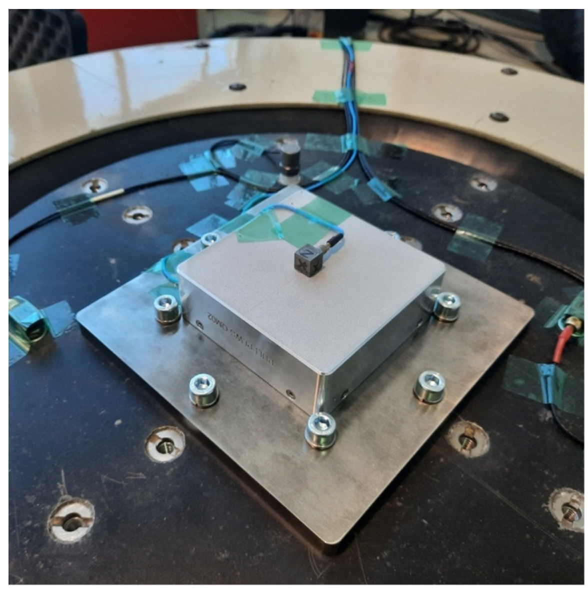

Fig. 3. PLWS on vibration test pad.

References: [**1**] Atwell et al. (2020) LSSW, Abstract #6011. [**2**] Robinson et al., LSSW 2021 #8034, (2021). [**3**] Martin et al., European Lunar Symp. 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 Surface Innovation Consortium 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