The CORGIE (Confirming Orbital Remote-sensing with Ground Information Experiments) Consortium: Gordon Chin[1] (Coordinator), Shahid Aslam[1], Carrie Anderson[1], Michael Barker[1], Dina Bower[2,1], Tilak Hewagama[2,1], and Tim Livengood[2,1], [1]NASA Goddard Space Flight Center (Code 693, Greenbelt, MD 20771), [2]Department of Astronomy, University of Maryland, College Park, MD 20742.

Introduction: The **CORGIE** consortium aims to develop a comprehensive package of Artemis astronaut deployed or operated experiments that confirm and extend orbital remote-sensing or orbital *in situ* observations of the lunar South Polar environment. The **CORGIE** are comprised of:

- **SSOLVE** (Submillimeter Solar Observation Lunar Volatiles Experiment)**, SNFLER (**Surface Neutron Flux – Lunar Empirical Ratio)**,**
- **ROCSTAR** (Rapid Optical Characterization Suite for *in situ* Target Analysis of Lunar Rocks),
- **CLuMI** (Compact Lunar Mineralogy Imager), and
- **Moonba,** a rover for microscopy/photometry**.**

CORGIE would highly benefit from being deployed and operated at distances well away from the Artemis landing site due to the contaminated blast zone.

SSOLVE and SNFLER are a powerful combination that measures the complete volatile content (H_2O and its photo-disassociated product OH) in a column from the surface to space. **SSOLVE** uses submillimeter heterodyne spectroscopy to measure the abundance of H_2O and OH while **SNFLER** measures the H-content within the 1-meter depth of the regolith by monitoring the epithermal and thermal neutron flux.

SSOLVE will use the Sun as a light source to illuminate the presence of water in the tenuous lunar atmosphere: its abundance, diurnal variability, chemical state (H_2O vs. OH), and the balance between sources and loss. The abundance of water in the tenuous atmosphere immediately above the daytime lunar surface has not been measured, although a wide range of estimates can be derived from measurements on orbit, remote sensing (Li and Milliken 2017; Livengood *et al.* 2015; Sunshine *et al.* 2009), and equilibrium between assumed supply and loss rates. These estimates vary by orders of magnitude. **SSOLVE** will measure the total column of H_2O and OH above the lunar surface with extremely high sensitivity and will be coupled with calibration measurements that will eliminate local contributions or instrumental contamination. **SSOLVE** will use high spectral resolution to identify transitions of H_2O, OH, and HDO with certainty, to measure abundance, and to characterize physics in the exosphere using Doppler linewidth from translational motion**.** The **SSOLVE** uses a heliostat to track the Sun and at other targets within 2π steradian.

SNFLER is a surface-deployable neutron flux sensor package to measure subsurface hydrogen in the regolith at meter scales, thereby establishing ground truth to interpret orbital mapping. Measurements of regional suppression in the Moon's naturally occurring leakage flux of epithermal neutrons have been used from orbit to map the location of hydrogen content in the near-surface regolith, with some ambiguities and challenges in calibration. At the surface, with zero relative velocity and near-fixed altitude above the regolith, a new mode becomes available in which hydrogen suppresses the epithermal neutron flux and promotes the thermal neutron flux. The ratio of flux measurements thus produces a dimensionless measure proportional to the hydrogen content that compensates for confounding effects from variable cosmic ray flux (the source of lunar neutrons) and from temperature effects on the neutron scattering cross-section. SNFLER measurements correlated with diurnal heating or illumination are vitally important to confirm orbital remote sensing measurements such as those reported by Livengood *et al.* 2015 and Sunshine *et al.* 2009.

ROCSTAR is a composite instrument combining Raman spectroscopy and reflectance spectroscopy that enable rapid, nondestructive, passive characterization of planetary surface materials to identify trace compounds without sample preparation. **ROCSTAR** implements mature vibrational spectroscopy techniques to prospect for chemical species that are critical to establish a viable long-term lunar exploration program thus enabling human presence on the Moon.

ROCSTAR identifies minerals and volatiles in lunar materials using a combined package of time-resolved visible (VIS) 532 nm and near-infrared (NIR) 785 nm Raman, complemented by near-Infrared/mid-Infrared (NIR-MIR) reflectance spectroscopy. These capabilities enable rapid quantitative measurements of lunar surface materials while reducing the need for mechanical or thermal processing to evaluate water and metal contents. Water is a priority resource essential to life support, facility operations, and synthesizing fuels. Mineral-bound metals are important resource targets in regolith and mare basalts (Taylor, G. J. and Martel, L. M. V. 2003). Lunar minerals ilmenite and pyroxene are known hosts of metals like Cr, Ni, Co, and Mn, and ilmenite in particular has been considered for Fe and O_2

extraction (James, O. B. 1973; Papike J., Taylor L., and Simon S. 1991).

Raman spectroscopy provides structural information to identify trace compounds, including minerals, in a matter of seconds. Raman spectroscopy has been used for decades to measure the composition of returned lunar samples and analog materials (Wang, A. et al. 2001; Jolliff, B. et al. 2006; Ling, Z.C. et al. 2011). Reflectance spectroscopy has a strong lunar mission heritage to build on, having been used for decades to evaluate the mineralogy of the lunar surface via remote measurements from orbital platforms like Galileo, Clementine, Lunar Prospector, and the Moon Mineralogy Mapper (M^3) on Chandrayaan 1, as well as multiple Earth-based telescope measurements (C.M. et al. 2009). The two complimentary techniques, used together, ensure near-comprehensive identification and accurate characterization of lunar materials suitable for resource extraction.

ROCSTAR's goal is to provide the means for *in situ* standalone identification of priority resource materials on the lunar surface with minimal power needs in a compact package. The architecture of **ROCSTAR** ensures adaptability to any mission platform, whether that be inside a lander/rover or extended on a robotic arm, or as a handheld device carried by astronauts. **ROCSTAR** can determine the composition, variety, and distribution of minerals, metals, and water with correlated spectroscopic measurements. These measurements are achieved by pointing **ROCSTAR's** probe at a target at a distance of a few mm with sequential activation of MIR-NIR reflectance acquisitions followed by NIR-VIS Raman acquisitions, each for ~0.5 – 40s integration time (depending on the target material).

CLuMI is a 2 - 12 µm hyperspectral imaging camera with a sensitive 1 Mpixel camera. **CLuMI** has a small form-factor (2.5 U), is low-mass (2 kg), low-power (10 W), and incorporates a focal plane integrated assembly of linear variable and discrete filters. The spectral response of the SLS sensor brackets the spectral signatures of ISRU-relevant compounds. A compact broadband visible imager bore-sighted with the infrared sensor will provide contextual images of the region being investigated.

Identification of lunar rock forming minerals (ilmenite, plagioclase, pyroxene, spinel, olivine, armalcolite), accessory minerals (*e.g.*, feldspar, and apatite), and trace minerals (*e.g.*, Silicates, Sulfides/sulfates) will guide requirements for mining exploitation. Recent studies suggest significant water deposits are possible in cold-traps (~100 billion metric tons). The common optical sensing technology is based on the 3 µm (~3200 - 3700 cm^{-1}, stretching-modes) vibrational bands associated with both water (ν_1/ν_3) and OH (ν_1). Discrimination of water from OH bearing minerals is critical for planning of mining operations. The 6 µm (1595 cm^{-1}, ν_2 bending-mode vibrational band) of monomer ice (e.g., I_h state) results in an emissivity peak unique to water (from OH) and also seen in dirty ice. One more signature of interest is the 12 µm (780 cm^{-1} libration) band. Combined with the 3 µm and 12 µm signatures, an instrument capable of sensing these bands will detect and distinguish water ice from OH in the matrix.

CLuMI is designed for use by astronauts as a standoff survey instrument in an automated, efficient manner while assuring safety of personnel and equipment. For example, optical sensing from a distance enables an astronaut to rapidly explore composition in a survey mode and peruse difficult to access terrains from a safe distance.

Moonba will be a small tele-operated rover transporting a microscope and lighting system to characterize the photometric properties and physical structure of undisturbed lunar dust and uncompacted regolith at a scale of ~10 µm per pixel over an imaging patch of a few cm width, along a transect of ~200 m. **Moonba** observations will sample local diversity of surface materials and structure, characterize micrometeorite impact sites *in situ*, and observe diminishing effects of site contamination as the rover recedes from the human-occupied area. Astronauts can transport and deploy the rover and base station to a remote location to distance it from the modified region surrounding the lander. The **Moonba** can be operated remotely from Earth or by astronauts. The **Moonba** will slowly drive into pristine terrain to avoid damaging the observed surfaces. Regularly programmed stops allow photomicrographs to be taken with forward-looking context and navigation views. Power and communication will be delivered over a lightweight cable deployed between the rover and base station. **Moonba** will take advantage of consumer electronics, albeit in a system engineered for the lunar environment. **Moonba** images may be retrieved from a storage device on the base station while transmitting only critical data to Earth.

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