Correlated Raman and Reflectance Spectroscopy for in situ Lunar Resource Exploration.

D. M. Bower[1], T. Hewagama[1], N. Gorius[2], S. Li[3], S. Aslam[3], P. Misra[4], T. A. Livengood[1] and J. R. Kolasinski[3], [1]University of Maryland College Park, College Park, MD 20742, dina.m.bower@nasa.gov, [2]Catholic University of America, Washington, DC 20064, [3]NASA Goddard Space Flight Center, Greenbelt, MD, 20771, [4]Howard University, Washington, DC, 20059.

Introduction: A composite instrument combining Raman spectroscopy and reflectance spectroscopy will enable rapid, nondestructive, passive characterization of planetary surface materials to identify trace compounds without sample preparation. The **R**apid **O**ptical **C**haracterization **S**uite for in situ **T**arget **A**nalysis of Lunar **R**ocks (**ROCSTAR**) is designed to search for minerals and volatiles in lunar materials using a combined package of time-resolved visible (VIS) 532 nm and near-infrared (NIR) 785 nm Raman, supported by near-Infrared/mid-Infrared (NIR-MIR) reflectance spectroscopy. ROCSTAR implements mature vibrational spectroscopy techniques to probe for chemical species of significance in lunar prospecting. Resource identification is critical to develop a viable long-term lunar exploration program enabling a continued human presence. ROCSTAR capabilities will enable rapid quantitative measurements on 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 [1]. 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 [2][3].

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 ([4][5][6] and references therein). 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 [7][8][9] The two complimentary techniques, used together, ensure near-comprehensive identification and accurate characterization of lunar materials suitable for resource extraction.

Science and Technology Goals: Our main goal is to provide the means for in situ standalone identification of priority resource materials on the lunar surface with minimal power needs in an 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).

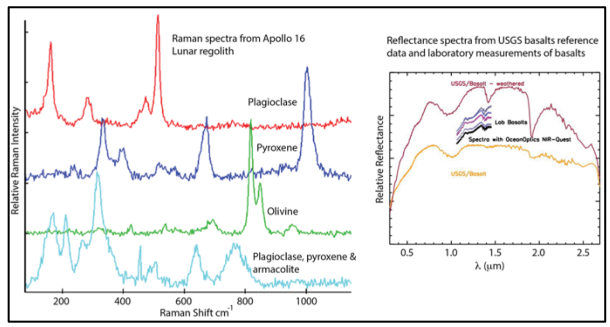

Figure 1 Preliminary Raman and reflectance data supporting the design of ROCSTAR; Raman measurements of multiple minerals in one lunar regolith sample under 532nm excitation and NIR measurements of basalts acquired in the laboratory with USGS data for reference.

References: [1] Taylor, G. J. and Martel, L. M. V. (2003) *Adv. In Sp. Res.*, *31*, 2403-2412. [2] James, O. B. (1973) XX. [3] Papike J., Taylor L., and Simon S. (1991) *in Lunar Sourcebook*, pg. 121. [4] Wang, A. et al. (2001) *American Mineralogist, 86,* 790-806. [5] Jolliff, B. et al. (2006) *American Mineralogist, 91,* 1583-1595. [6] Ling, Z.C. et al. (2011) *Icarus, 211,*101-113. [7] Charette, M.P. et al. (1974) *JGR, 79(11),* 1605-1613. [8] Chevrel, S.D. et al. (2002) *JGR, 107(E12),*15-1 -15-14. [9] Pieters, C.M. et al. (2009) *Science, 326(5952),* 568-572.