EPSC Abstracts
Vol. 9, EPSC2014-657, 2014
European Planetary Science Congress 2014

Lunar Robotic Arm Camera (L-RAC) for Future Missions to the Moon

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Abstract

In the context of the development of many missions dedicated to the exploration of the Moon with landers and rovers, we present the Lunar Robotic Arm Camera (L-RAC), a powerful instrument dedicated to the close-up investigation of the surface rocks and regolith.

1. Introduction

The renewed scientific interest for the Moon that have been observed for more than 15 years is still ongoing, with lunar exploration missions currently in development by many countries: India (Chandrayaan-2, 2015 [1]), China (Chang'e 5, 2017 [1]), Russia with possible ESA contribution (Luna-25, 2015; Luna-26, 2018; Luna-27, 2019; Luna-28 and Luna-29, 2020+ [2]), USA (Resource Prospector, 2018 [1]), Japan (Selene-2, 2018 [3]). Most of the effort appears now focused towards sample return and preparation for future human missions. In this respect, knowledge of the surface characteristics is paramount, and valuable information can be acquired by close-up imaging instruments mounted on a robotic arm on a lander or rover, such as the Lunar Robotic Arm Camera (L-RAC) described here.

2. L-RAC Characteristics

L-RAC is a powerful, miniaturized, low-power robust compact system, which includes a focusing system to vary the working distance from 10 cm to infinity. Based on the CLUPI (Close-UP Imager [4] [5]) instrument currently developed for the ESA ExoMars 2018 mission, the L-RAC is composed of optics with focus mechanism, a high-resolution colour image detector (Active Pixel Sensor, 2652 x 1768 x 3 pixels, spectral range: 400–700 nm), and electronics that perform all functions, among which detector control, converter, memory, complex processing (autofocus, automated exposure time, binning, windowing, z-stacking), data handling and protocol, by using FPGA.

The L-RAC colour detector keeps the spatial resolution so that no Bayer filter is needed. With a field of view of 14° ± 2° diagonal, the imaged surface is about 1.9 x 1.3 cm^2 at 10 cm distance with 7.2 µm/px resolution, 21 x 14 cm^2 at 100 cm distance with 79 µm/px resolution. Once the robotic arm has performed the orientation of the L-RAC to the target, the instrument's optics will perform autofocus before taking images. Thanks to the focus mechanism (mobile lenses), the instrument can take images of an object with different working distances that would therefore be sharp on different areas of the images. Using an embedded z-stacking algorithm, it is then possible to combine all those images to produce an image sharp on every part of the object. With this process, a z-staking map is generated, containing the object distance information and enabling the creation of a numerical model of the local microtopography. Z-stacking thus induces a reduction of the data produced by the instrument by downloading more information-rich images. These characteristics make it a highly preforming instrument for lunar regolith and rock studies from a lander or rover, as well as for sampling activities.

3. Scientific Objectives

The primary objectives of the L-RAC are to perform the local characterization of the landing site or rover close environment and study the physical properties of the lunar regolith, from larger rocks to grains down to the order of 10 µm in size. The production of sharp close-up images in the visible domain provides information on the shape, structure, size distribution, roughness, etc., of the particles.

Besides, the technical performances of the L-RAC make it possible to carry out several specific types of analysis of the lunar regolith: multiscale analysis of surface roughness, thanks to the variable focusing length that allows imaging of the same surface from different heights, from microscopic to macroscopic scales; (stereo-) microtopography, phase ratios, and photometric studies, by acquiring images of a same area and at the same resolution from various emission angles using the mobility of the robotic arm.

The L-RAC can be used in synergy with other instruments to link together visual (e.g., stereo panoramic imaging) and compositional (e.g., spectrometer) information to obtain a thorough characterization of the studied lithologies at all scales.

If part of a sampling mission, the L-RAC can acquire geological data about the sample and its close environment before and after its collection, monitor the sample selection, acquisition and subsequent operations by the robotic arm. It can also gather data on the mechanical properties of the regolith due to the disturbance by the sampling process.

As regards lunar dust properties, crucial to understand for the exploration of the Moon, the L-RAC can carry out temporal surveys throughout the mission, such as dust / regolith particles adhesive properties and dust rate of adhesion on various surfaces of the lander / rover.

4. Summary and Conclusions

The L-RAC offers a powerful and polyvalent means for the lunar surface investigation. Derived from the CLUPI instrument for the ExoMars 2018 mission, it benefits from an already highly developed concept. Its scientific performances makes it valuable for regolith and rock studies, especially if placed on a robotic arm, as well as for sampling activities monitoring.

Acknowledgements

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