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Lunar Active Experiment (LAX) for Lunar Water Investigations

Y. Futaana, S. Barabash, M. Holmström, G. Stenberg Wieser, X. D. Wang, M. Wieser, M. Yamauchi, M. Persson, A. Pontoni, P. Wittmann, and the SELMA team
Swedish Institute of Space Physics, Box 812, Kiruna SE 98128, Sweden (futaana@irf.se)

Abstract

The lunar environment is characterized by complex interactions among several domains. Due to the lack of the atmosphere, the lunar surface, exosphere, space plasma, and dust are a closely coupled system. It is entirely different from that at Earth, while similar environments can be found elsewhere in the Solar System. The proposed experiment, LAX, Lunar Active Experiment, aims to investigate these couplings by actively disturbing the system and monitoring its responses through remote sensing in various wavelengths and particles. LAX is an equipment installed onto the Deep Space Gateway with two main modules: the Lunar Impacting Module (LIM), injecting a projectile with sizes of 0.1–10 kg depending on the experiment and the Remote Sensing Module (RSM), monitoring the response. LIM can be re-charged by the crew allowing various impact experiments.

1. Science background

The complex environment of the Moon is characterized by couplings of the surface, exosphere, dust, and the plasma [1]. In particular, several independent measurements claim the existence of water at the lunar surface and the cold traps, but its dynamics, including the source, transport, loss mechanisms are not fully characterized. We proposed the mission SELMA (Surface, Environment, and Lunar Magnetic Anomalies), which also planned to study such interactions, in response to the ESA's M5 mission call.

An area of particular scientific interest where the Deep Space Gateway can contribute is the study of the water (or hydroxyl) at the top-most layer of the lunar surface, and its coupling to the environment, including the exosphere, magnetic anomalies, and dust. Top-surface lunar water was first observed by infrared spectroscopy (e.g., [2]), and it exhibits a diurnal variation (e.g., [3, 4]). Recently, Wöhler et al. [5] reported a reduction of surface water signatures in the South Pole Aitken, where a local magnetic field can shield the proton flux precipitating onto the surface [6]. These measurements indicate that the solar wind proton precipitation is a strong candidate for surface water production. Transport (or loss) of such water is yet unknown, in particular the transport to cold traps at the lunar poles is not solved. The Lunar South Pole has several permanently shadowed regions where water molecules are thought to be stored in a form of ice. An impact experiment by L-CROSS mission [7] concluded that up to 6% of the surface materials in the Cabeus crater is water (likely ice). However, how much water exists is still controversial, mainly because different measurements led to different conclusions on the water content distributions. Most likely, states of the ice (e.g. embedded depth of the ice cube) are the reason for the contradicting observations.

2. Equipment and DSG

LAX is composed of two permanent units. Lunar Impacting Module (LIM) and Remote Sensing Module (RSM). LIM is a module to inject an impactor with a volume of up to 1 liter and a mass of 0.1–10 kg from the Deep Space Gateway. RSM will monitor the signatures of the lunar surface. RSM is equipped with four remote-sensing sensors and a dust monitor. RSM remote sensing sensors are an infrared spectrometer, with a wavelength coverage of 1.5–3.6 μm, a UV spectrometer, with a wavelength covering 115–315 nm, a visible camera and an energetic neutral atom (ENA) sensor. These wavelength ranges are optimized for water absorption bands, but by extending the IR wavelength to 3.6 μm we can mitigate the ambiguity of thermal background, which has been a problem of existing IR measurements (e.g. [2]). The UV wavelength range is also capable of exospheric gas composition measurements. The ENA spectrometer can detect the solar wind flux and the speed at the lunar surface, which we can directly correlate with the surface water signatures. RSM also includes dust monitor. Impact experiment (as well as natural meteoroids) can produce dust, which may potentially reach to DSG. The mass flux and the speed characterize the response of lunar regolith to the impact experiment (and bombardment of natural meteoroids). Dust monitoring also mitigates the potential hazard for the crew during DSG activities. Instrumentations are based on the proposed SELMA mission [1].

The unique idea of using the Deep Space Gateway and its crews is that the projectiles can be prepared right before the ejection. For example, we may even suggest to launch a water ice cube to emulate a comet nucleus. Such preparation and curation of projectiles and LIM recharging are only possible with manned missions.

Ideas for projectiles and the science

• Copper ball (or equivalent) with 10 cm diameter, impacting at cold traps to make a dust and water plume. See [1] for details.

• Copper ball (or cubesat) to impact a magnetic anomaly in order to monitor the volatile motion and its difference to other un-magnetized areas. See [1] for details

• Water ice cube impacting to the surface to make artificial "pond" of surface water to simulate a cometary nucleus impact

3. Expected impact

The active experiment conducted by LAX provides multiple opportunities of projectiles. Such repeatable controlled impacts provide a statistical view of the water contents inside the cold traps, as well as insights on the transport of the water molecules.

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