INVESTIGATION OF LUNAR SWIRLS FROM THE SURFACE AND THE ORBIT

Authors: B. Soundararajan[1], I. Varatharajan[2], H.Gunasekar[1], J. Helbert[2], and I. A. Crawford[3]

[1]Institute für Luft und Raumfahrt, Technical University of Berlin, Marchstrasse 12-15, 10587 Berlin, Germany (balaji.soundararajan@campus.tu-berlin.de; hariharan.gunasekar@campus.tu-berlin.de), [2]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (indhu.varatharajan@dlr.de; joern.helbert@dlr.de), [3]Department of Earth and Planetary Sciences, Birkbeck College London, Malet Street, WC1E 7HX, UK (i.crawford@bbk.ac.uk)

Scientific Domain:
Solar System Sciences

Idea Description:

Space weathering is a prominent and continuous process that affects the chemical, physical and optical properties of the surface of airless bodies. This highly affects the study of mineralogy of surface materials from orbital spectroscopy. Among various space weathering agents such as solar winds, micrometeorites, cosmic rays, impact and thermal weathering the lunar surface has been effectively weathered by irradiation, implantation, and sputtering from solar wind particles, and bombardment by micrometeorites. There is a long-standing debate in their relative contribution to the weathering of the upper layer of the lunar regolith.

Lunar swirls are enigmatic high albedo and complex sinuous shape features distributed across the lunar surface. The Moon has no intrinsic magnetic field but these swirls are associated with locally high magnetic field strength. These mini-magnetospheres around the swirls deflect the impacting solar wind ions due to the shielding magnetic field. This reduces the effects of space weathering due to ion implantation and sputtering; however, the magnetic field cover cannot screen out micrometeorites. These swirls have been studied over decades by Apollo sub-satellite magnetometers, Lunar Prospector (1998–1999), Kaguya (2007–2009), Chandrayaan-1 (2008–2009), and Nozomi (1998) spacecraft. However, the origin and nature of swirls still remain a mystery.

This makes lunar swirls a natural laboratory that would help us to investigate the importance of micrometeorite bombardment vs. solar wind sputtering/implantation processes in the optical weathering of lunar regolith. In-situ exploration of two major swirls on geologically distinct lunar terrains, 1. Mare filled nearside (Reiner Gamma; 7.5°N, 302.5°E) and 2. Highland crust on lunar farside (Firsov; 10.5°S, 16.5°E) will help us to bridge the gap between lunar geology, planetary magnetism, space weathering and remote sensing. The results from the investigation can therefore be extended to space weathering processes in other airless rocky bodies such as Mercury and Vesta.

The proposed Lander-Rover-Modules (LRMs) deployed from the Deep Space Gateway (DSG) to both of the selected swirls from the NRHO/HALO orbit and therefore perform simultaneous investigation of these swirls on both lunar nearside and farside. Each LRM will have a lander and a rover, which will be launched separately from DSG satellite deployment ports/robotic arms to overcome the total mass (dry mass+fuel mass) constraints. The existing Canadarm in the ISS has capabilities to handle payloads up to 3000 kg. With this legacy, small LRMs can be easily launched from one of the robotic arms. As an alternative, assuming the existing technology of cubesat deployment from "NanoRacks Cubesat Deployer" in ISS is evolvable, the LRMs can also be considered launching from the DSG through such ports. Each Lander in LRM will carry a surface magnetometer (will constrain the depth and thickness of magnetic anomaly source region), solar wind spectrometer (will measure the solar wind flux reaching the surface), and seismometer (will record lunar seismicity on nearside and farside) and each rover in LRM will carry the UV-visible-NIR hyperspectral imagers (will detect the mineralogy, volatiles and constrain optical maturity spectral index wrt $npFe^{0}$), IR Radiometer (will measure thermo-physical properties of upper lunar regolith) microscopic imager (will detect the particle size distribution), and Mössbauer spectrometer (will measure $npFe^{0}$). The highlight of this proposal is that the simultaneous in-situ investigation of lunar nearside and farside swirls, lunar crust, magnetism, and seismicity has never been attempted before.

LRMs are of semi-automatic type and can be assumed to be of cylindrical shaped with body mounted solar panels. The casing of the LRM shall be made of lightweight composite material (such as Carbon Fiber Reinforced Plastic). Each lander shall have a maximum dry mass of 10 kg and the rover shall have a maximum dry mass of 15 kg with capability of traversing few hundred meters within the lunar swirls. Along with the primary instruments mentioned above, a deployable antenna for communication shall be included for tele-operation of rover, and for data transmission between the LRM and the DSG. LRMs shall be fitted with small packets of solid boosters externally, which are used for de-orbiting into Low Lunar Orbits, controlling the attitude and for propulsive landing on the swirls, with at least two thrusters operating at a time. As the lunar swirls are wide in nature (30 to 100 km), the LRMs shall land anywhere within the swirls and the rover shall be moved around. This eases the requirement for precision landings.

The primary reason to go for DSG based deployment and tele-operations is to perform in-situ study on the lunar swirls that are spread widely in nature using tiny LRMs. The control of the LRMs instruments operation, sample selection and testing and precise motion control of rovers is only possible through tele-presence. Also, DSG based operations will enable the technology demonstration of deployment of 'tiny' LRMs from small satellite launching ports/Robotic arms. More than just cubesat deployment, DSG should also have capabilities to launch LRMs, at least for applications those does not require precision landing as in the case of Lunar swirls study. The entire duration of the mission shall be last for at least one lunar day/night cycle. The sample return concept is avoided here mainly because of the complexity of the ascent vehicle and higher fuel consumption required.

Table: Expected equipment and operational needs. Please complete this table where you can but feel free to leave blank where you are unable or unsure of how to complete it.

Estimated experiment properties	Description
Mass of hardware	-Total mass of 1 Lander (approx): 130 kg (Dry mass of 10 kg, fuel mass of 120 kg) -Total mass of 1 rover (approx): 165 kg (dry mass of 15 kg, fuel mass of 140 kg)
Volume of hardware	TBD. Volume shall accommodate small satellite deployment port of DSG
Accommodation (e.g. internal/external)	Volume for instruments. TBD
Power required	Instruments for Lander: 60-100 W (approx) Instruments for Rover: TBD
Data generated	TBD
Pointing/viewing/line of sight needs	Pointing of antennas towards DSG or Low lunar orbiting satellites for tele-operations/data transfer
Communications needed	TBD. As required for tele-operations
Duration of experiment	At least one day/night cycle
Crew tasks (if needed)	1.Deployment of Landers and Rovers (2 sets for 1st mission) 2. Control of Lander instruments/rovers
Access and servicing by crew (if needed)	Same as above
Need for retrieval and return to Earth	No, Data alone is essential
Specific orbit needs (if any)	NRHO, or anything similar for deployment purposes and tele-operations. Lagrangian orbits will increase Delta V slightly
Operations without crew (if any)	TBC