A Dedicated Small Lunar Exploration Orbiter (S-LEO) and Mobile Payload Element (MPE)

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The Moon is an integral part of the Earth-Moon system, it is a witness to more than 4.5 b. y. of solar system history, and it is the only planetary body except Earth for which we have samples from known locations. The Moon is thus a key object to understand our Solar System. The Moon is our closest companion and can easily be reached from Earth at any time, even with a relatively modest financial budget. Consequently, the Moon was the first logical step in the exploration of our solar system before we pursued more distant targets such as Mars and beyond. The vast amount of knowledge gained from the Apollo and other lunar missions of the late 1960's and early 1970's demonstrates how valuable the Moon is for the understanding of our planetary system (*e.g. Hiesinger and Head, 2006; Jaumann et al., 2012*). Even today, the Moon remains an extremely interesting target scientifically and technologically, as ever since, new data have helped to address some of our questions about the Earth-Moon system, many questions remained. In particular, water at the lunar poles, water and hydroxyl bearing surface materials and volatiles changed our view of the Moon as well as the discovery of young volcanism. Therefore, returning to the Moon is the critical stepping-stone to further exploring our immediate planetary neighborhood. Here, we present scientific and technological arguments for a Small Lunar Explorations Orbiter (S-LEO) dedicated to investigate so far unsolved questions and processes. S-LEO is designed to improve our understanding of the lunar environment in terms of composition, surface ages, mineralogy, physical properties, and volatile and regolith processes. S-LEO will carry an entire suite of innovative, complementary technologies, including high-resolution camera systems, several spectrometers that cover previously unexplored parts of the electromagnetic spectrum over a broad range of wavelengths, and a communication system to interact with landed equipment on the farside. The Small Lunar Explorations Orbiter will gather unique, integrated, interdisciplinary data sets that are of high scientific interest and will provide an unprecedented new context for all other international lunar missions.

The most visible mission goal of S-LEO will be the identification and mapping of lunar volatiles to understand their origin and evolution with high spatial as well as spectral resolution. Therefore, in addition to mapping the geological context in the sub-meter range, a screening of the electromagnetic spectrum within a very broad range will be performed. In particular, spectral mapping in the ultraviolet and mid-infrared will provide insight into mineralogical and thermal properties so far unexplored in these wavelength ranges. The determination of the dust distribution in the lunar orbit will provide information about processes between the lunar surface and exosphere supported by direct observations of lunar flashes. Measuring of the radiation environment will finally complete the exosphere investigations. Combined observations based on simultaneous instrument adjustment and correlated data processing will provide an integrated geological, geochemical and geophysical database that enable

- the exploration and utilization of the Moon in the 21st century;
- the solution of fundamental problems of planetology concerning the origin and evolution of terrestrial bodies;
- understanding the uniqueness of the Earth-Moon System and its formation and evolution.
- the absolute calibration of the impact chronology for the dating of solar system processes.

- deciphering the lunar regolith as record for space environmental conditions.
- mapping lunar resources.

S-LEO is featuring a set of unique scientific capabilities w.r.t. other planned missions including: (1) dedicated observation of volatiles (mainly H_2O and OH), their formation and evolution in direct context with the geological and mineralogical surface with high spectral and spatial resolution (< 1m/px). (2) Besides the VIS-NIR spectral range so far uncovered wavelengths in the ultraviolet (0.2 – 0.4 µm) and mid-infrared (7 - 14 µm) will be mapped to provide mineralogical context for volatile processes (e.g. sources of oxygen). (3) monitoring of dust and radiation in the lunar environment and its interaction with the surface.

In addition a Mobile Payload Element (MPE) can assist a lunar lander mission. The MPE is under study in Germany with the goal to collect uncontaminated and undisturbed samples outside the lander area. The MPE shall acquire samples of regolith with landing-induced contamination being *below* the detection limit of the associated volatile-seeking instruments; subsurface regolith sampling is preferable to understand the concentration of volatiles as a function of depth. Chances for encountering elevated volatile concentrations in regolith are dramatically increased if samples are acquired from permanently shadowed patches of terrain; these may be found close to the lander under overhangs of large boulders; moreover, also regolith directly underneath sufficiently large (metre-sized) boulders will have been efficiently 'shadowed' for long periods of time and will be at lower average temperature than the surrounding surface soil which is favourable for preservation of volatiles; thus, regolith from under boulders may be samples of choice for the MPE provided there is a way to access it. The MPE shall make the samples accessible to analyses by instruments capable of measuring volatiles. Additional benefits for the overall science accomplished by a lunar lander mission could be obtained if the MPE were to conduct 'field geology' type observations and measurements along its traverses, such as geochemical and mineralogical in situ investigations with dedicated instruments on rocks, boulders and regolith. This would dramatically expand the effective area studied by the ESA Lunar Lander mission. As both the lander-based instruments are conceived to ingest regolith, one unique scientific aspect of the MPE could be the in situ study of rocks, boulders and lithic (rock) fragments which otherwise would only be amenable to measurements using any instrument heads mounted on the lander robotic arm (provided any rocks were within reach of the arm). Rocks and rock fragments carry unique, individual histories of igneous, impact and volcanic events from local and distant sources.

H. Hiesinger, J.W. Head, New Views of the Moon (B.L. Jolliff et al. eds.) Rev. Min. Geochem., 60, 1-81(2006).

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