A DEDICATED SMALL LUNAR EXPLORATION ORBITER AND A MOBILE SURFACE ELEMENT.

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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. [1], [2]). Even today, the Moon remains an extremely interesting target scientifically and technologically. New data have helped to address some of our questions about the Earth-Moon system, but many remain and new questions arose. In particular, the discovery of water at the lunar poles, and water and hydroxyl bearing surface materials and volatiles, as well as the discovery of young volcanism have changed our view of the Moon. 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. Numerous space-faring nations have realized and identified the unique opportunities related to lunar exploration and have planned missions to the Moon within the next few years. Among these missions, S-LEO will be unique, because of its unprecedented spatial and spectral resolutions. S-LEO will significantly 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 concept is technologically challenging but feasible, and 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 and investigating 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 enables:

- 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) detection of rock-forming elements by means of x-ray fluorescence in the spectral range of .5-10 keV in order to constrain the composition of key elements of lunar surface materials; (4) monitoring of dust and radiation in the lunar environment and its interaction with the surface; and (5) monitoring of present-day meteoroitic impacts.

In 2009 ESA commissioned a Mobile Payload Element (MPE) to assist the ESA Lunar Lander mission. The MPE, currently under study in Germany, is designed to be a small, autonomous, innovative vehicle of roughly 10-12 kg for scouting the environment in the vicinity of the lunar landing site. The novel capability of the MPE will be to acquire samples of lunar soil in an area of >100m around the lander and to bring them back to the spacecraft for analysis by on-board instruments. This will enable access to soils that are less contaminated by the descent propulsion system plumes to increase the chances of detection of any indigenous lunar volatiles. 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. 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. Based on technology trades the baseline concept for the MPE system is composed by a 4-wheel active chassis with wheels, a power supply with fixed solar generators plus a secondary battery, a thermal system with active heating and passive insulation, a sensor package for autonomous operations and a VHF/UHF communication system between MPE and the Lander. 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). To fulfill the science objectives, the MPE will be equipped with a stereo camera, the PLUTO mole subsurface regolith sampling system (as flown on Beagle 2) as well as a close-up imager. This instrument package allows acquisition of regolith samples from both illuminated and locally shaded terrain, sampling from the subsurface and from underneath large boulders and documentation of the samples acquired by close-up imaging of the sample site, ideally before and after sample acquisition. A suite of terrain temperature sensors is implicitly included to provide context for the samples acquired from permanently shadowed locations or below the surface, but also to contribute to landing site general science. As an option for the in-situ characterization of the sample material with respect to mineralogy and possibly volatile content, spectrometer experiments or a color capability of the camera could be added.

Further, a laboratory environment is currently being established at Freie Universität Berlin in order to allow sample-based geochemical measurements of key rock-forming elements in the soft X-Ray domain (.5-10 keV). The laboratory is used for the hardware development of X-Ray spectrometer experiments to be employed on lunar orbiter and on lunar lander missions.

References:

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