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SOLVE: a small spacecraft for near lunar environment exploration

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Abstract

SOLVE (Small spacecraft fOr near Lunar enViroment Exploration) is a novel mission proposal to employ a 12U CubeSat which will be deployed by a lunar orbiter providing transportation and data relay services. SOLVE will characterize the Lunar environment by studying the complex set of interactions between radiation, illumination, plasma, magnetic field and dust in dependence of altitude. It will decrease its orbit gradually from 500 km altitude in a controlled way until it finally reaches the surface with an attempt to land softly. Besides the above-mentioned geophysical variables, the radiation environment relevant to humans will be measured along the trajectory by detecting highly penetrating ionizing particles (GCRs and SEPs). SOLVE will provide a unique opportunity for demonstration of new and innovative technologies. It will have propulsion systems enabling high Delta-V maneuvers and state-of-art attitude determination and Control System (ADCS) of relevance to future CubeSat missions. Demonstration of small landers for the Moon would open new science opportunities and exploration possibilities that may lead to future geophysical network stations on the Moon as well as other solar system bodies.

1. Introduction

The Moon is key to understand the early history and evolution of the Solar System, in particular it is a fundamental source of information on the origin and evolution of rocky planets and on the Earth–Moon system. The lunar surface is directly exposed to the harsh space environment, including a continuous bombardment by interplanetary large and small impactors, high energy radiation, UV/X-rays, and solar wind plasma. The remnant magnetic fields might allow an accumulation of solar wind plasma near the lunar surface.

The tight coupling between magnetic field, electric field, plasma, radiation and dust makes the understanding of lunar near surface environment and exosphere challenging. By exploring these couplings relative to the altitude SOLVE will shed light onto fundamental processes relevant to space weathering processes, dust transport, origin, migration and preservation of volatiles, and will help to identify the effects and hazards of the dusty plasma environment on future robotic and human exploration.

2. Science investigations

The SOLVE mission has three primary (S#1 – S#3, outlined in detail below) and three secondary (S#4 – S#6) science objectives:

S#1	Ionosphere investigation (and dust in orbit)
S#2	Crustal magnetic anomalies
S#3	Radiation environment relevant for humans
S#4	Surface dust
S#5	Thermal environment
S#6	Dynamical state

2.1 Ionosphere investigation

Today, there is no general consensus on the electron density and altitude ranges of the lunar ionosphere, on the physicals mechanism for producing the high electron concentrations observed in the lunar environment, and if the ionosphere is gas or dust dominated. Two different and independent methods for determining the electron content will be used: the first is radio occultation, in order to obtain the total electron content along the line of sight (TEC), the second is Langmuir probe measurements for an in-situ measurement of the electron density and temp-erature. By sweeping the Langmuir probe potential in the ion saturation region (negative potential with respect to the plasma potential) the mass-to-charge ratio of the positive ions - or dust grains - can be estimated [1].

2.2 Crustal magnetic anomalies

In-situ measurements of lunar crustal magnetic anomalies are required to fully understand the nature of anomalies and the various processes such as solar wind interaction with crustal anomalies, origin of the lunar “swirls”, space weathering history of the core dynamo, paleomagnetic pole positions, etc. Especially close to the surface is a lack of such measurements. A network of small magnetometers distributed within the spacecraft and on short booms will be used and their signals combined in order to separate ambient field from spacecraft-generated magnetic perturbations.

2.3 Radiation environment relevant to humans

The radiation exposure is considered to be one of the main health detriments for humans in space and poses a limiting factor for long duration space flights. While on the Moon the solar wind can be shielded with a reasonable amount of mass, galactic cosmic rays (GCRs) and solar energetic particles (SEPs) are highly penetrating up to several meters within the lunar surface. But no surface measurements have been performed since the Apollo missions. With a two element silicon detector telescope [2], which can measure minimal ionizing protons up to GCR iron ions, the linear energy transfer (LET) spectra, the absorbed dose and dose rates can be derived, which will give a good estimate of the dose equivalent.

3. Mission scenario

The mission consists of several phases, including the orbit injection into a 500 km circular orbit; measurements from a stable orbit around Moon; a descent phase, in which the measurement parameters are obtained as a function of altitude down to the lunar surface; after a soft landing (if achievable), operation continues on the surface. Different scenarios are under investigation. One of the possible scenarios considers a stepwise descent down to the surface, using a total Delta-V of about 100 m/s. Additionally a large Delta-V maneuver will be required in order to land softly on the lunar surface. A soft landing requires a total Delta-V of about 1.8 km/s. Preliminary analysis shows promising results, however, even if the soft landing fails, primary science objectives will be fulfilled during the previous mission phases.

4. CubeSat and instrumentation

SOLVE is a 3-axes stabilized 12U CubeSat based on the XCube platform [3]. Due to the large Delta-V requirement, the propulsion and ADCS system are the main design drivers for the spacecraft. The second is the harsh thermal environment on the lunar surface.

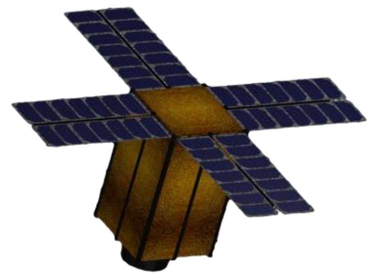

Figure 1: XCube platform.

The spacecraft and instruments are partly based on ESA’s SIMBA and PICASSO CubeSats [4] and on the Asteroid Geophysical Explorer (AGEX) [5], which was part of ESA’s CubeSat Opportunity Payload Intersatellite Network Sensors (COPINS). The payload consists of a radio transponder (S- or X-band), a Langmuir probe, UV sensors, several small magnetometers, a two-element particle detector telescope, surface charge probes, thermal sensors and retro-reflectors.

References

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