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On feasibility of Moon remnant magnetic field measurements with a CubeSat mission

M. Alho[1], E. Kallio[1], J. Praks[1], E. Tanskanen[1], B. Riwanto[1], P.Peitso[1], J. Envall[2], P. Janhunen[2], M. Väänänen[1]
[1]Department of Electronics and Nanoengineering, School of Electrical Engineering, Aalto University, Finland, jaan.praks@aalto.fi
[2]Finnish Meteorological Institute, Space Research, P.O. Box 503, 00101 Helsinki, Finland

Abstract

In this paper, we propose a CubeSat mission for mapping Moon remnant magnetic field and discuss various technical aspects and difficulties, such as instrumentation for weak magnetic field measurement, magnetic cleanliness of the CubeSat platform, orbit and orbital maneuvers. The mission would give information about the history of the Moon and possibly help to better plan lunar bases and manned missions.

1. Introduction

According to current knowledge, the Moon has no inner dynamo which could generate magnetic field. However,the lunar crust still has weakly magnetic regions, magnetic anomalies, which tell us about the evolutionary history of the Moon. The lunar magnetic anomalies range in intensity from tens of nano-Tesla up to a micro-Tesla at the lunar surface, some possibly able to stand off the impinging solar wind and create miniature magnetospheres. Recently, Arkani-Hamed and Boutin [1] published a study stating that the *Lunar Prospector* magnetometry data points both to a lunar dynamo and pole wander and magnetic reversals. The anomalies are also curiously antipodal to impact basins, pointing to a mechanism of formation related to the massive impacts. The plasma environment of lunar magnetic anomalies also provides for a unique plasma laboratory at ion and electron kinetic scales, and may have consequences for the electric and charged dust environment at the lunar surface at these sites. This may be of importance to planning of lunar bases.

2. Mission goals and orbit

The mission goal is to provide accurate measurements of the magnetic field produced by the lunar magnetic anomalies, at low altitudes (down to < 10 km) and at a high spatial and temporal resolution, to provide for more accurate general description of the crustal magnetic fields and plasma processes at and around the magnetic anomalies. In order to achieve a low enough orbit, the orbital altitude should be decreased gradually and therefore an elliptical orbit is proposed. To lower the orbit, e-sail technology in solar wind [2] can be used. A polar Moon orbit would allow to scan slowly the surface and form a map of magnetic field. The e-sail technology, required for orbital maneuvers, is currently being tested on board of many CubeSat missions, including Aalto-1 mission, operated by the authors.

3. Scientific instrumentation

The main instruments of the mission will be (1) a fluxgate magnetometer and (2) MF/HF radio instruments, both developed at Aalto University, and (3) a Langmuir probe. Due to the nature of the measurable phenomenon and the accuracy requirements, a boom mount will be designed to accommodate the magnetometer. Though somewhat uncommon in CubeSat platforms, several boom designs have been proposed by the community. The measurement requires also additional cleaning from spacecraft platform induced magnetic noise an several more magnetometers inside the spacecraft and boom. The Langmuir probe (made by university of Oslo) is already used on board of Aalto-2 satellite, however, longer probes are needed to measure the electron density in the tenuous Lunar plasma magnetic anomaly region. The HF/HF frequency range radio wave instrument, which is onboard Suomi 100-satellite, enables to measure possible electromagnetic disturbances caused by the magnetic anomaly.

4. Satellite platform and magnetic cleanliness

In order to have better estimates on magnetic disturbances inside the Aalto-series CubeSat platform, Aalto-1 and Aalto-2 satellite magnetometer readings

are used [3]. In Aalto-1 satellite, we expect for the spacecraft to have a total residual magnetic moment of 58.5e-3 Am^3. For Aalto-1 configuration, this residual magnetic moment translates into an offset of 2000-5000 nT in the magnetometer reading. Depending on the sensitivity of the magnetometer, its noise level, and the configuration of the satellite bus used in the scientific mission, the magnetometer for Lunar magnetic mapping might require a deployed boom system to minimize the influence of the spacecraft remnant magnetic field. Detailed magnetic environment simulations based upon previous CubeSat missions will be undertaken to further strengthen the calibration of the magnetometer [4]. Also, in order to achieve required signal cleanliness, the spacecraft influence should be removed from the signal as well as possible.

5. Satellite Platform

The CubeSat platform has strong size limitations which poses challenges for communication, as large antennas are difficult to implement. Additionally, attitude control cannot rely on magnet torquers and therefore a propulsion system is needed to load off the reaction wheels. To some extent solar wind sail can be used to also orient the satellite, however, to achieve full control of the attitude, also a more versatile gas propulsion system is needed. To fit all required instruments to the satellite, we propose that a 6U 8 kg CubeSat with deployable solar panels can be used. The platform wold provide enough power for communication, around 10 W, to be operable already with relatively small ground station.

6. Summary

In this paper we proposed a CubeSat mission to map Moon remnant magnetic field and discussed various technical aspects of the mission. The biggest challenge is to acquire good signal level in a very tiny satellite. Therefore a very sensitive sensor should be used and various signal cleaning algorithms are proposed. The mission features also plasma temperature measurement instrument and radio noise measurement instrument. The consortium behind this proposal has some experience on all proposed instruments on board CubeSat platform.

References

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