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

J. Praks[1], M. Alho[1], E. Kallio[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, Aalto University, FI-00076 Aalto, Finland
(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. The mission would give information about the history of the Moon and possibly help to better plan lunar bases and manned missions. Moreover, the mission could shed light to origin of lunar swirls.

Motivation

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 nanotesla up to a microtesla at the lunar surface, some possibly able to deflect the impinging solar wind and create miniature magnetospheres. It is also speculated that lunar swirls are connected to magnetic anomalies. 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.

Mission goals

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 and make orbit adjustment we propose that e-sail-based 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.

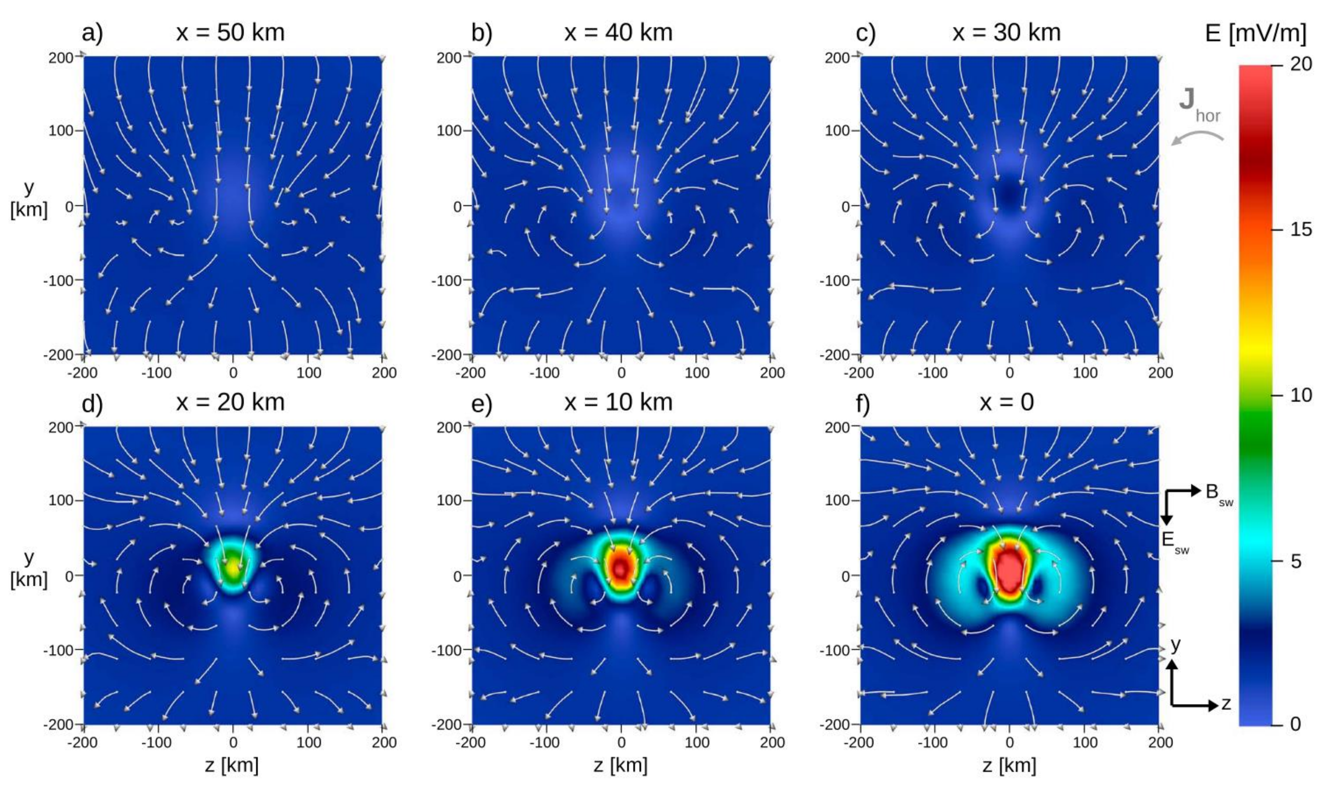

Figure 1. *Horizontal (yz) cuts of a lunar magnetic anomaly in the HYB-Anomaly hybrid simulation at x = 0...50 km altitudes. The color map shows the magnitude of the electric field, and the curved gray arrows give the morphology of the horizontal component of the electric current density [3].*

Satellite design and instrumentation

The satellite is designed around 12U CubeSat body and features spinning electric sail installation and magnetometer boom. Additionally the satellite has cold gas attitude system. The communication subsystem uses UHF radio omnidirectional beacon and S-band communication link with high gain antenna. The power is produced with solar panels.

The satellite has four payloads:

- Fluxgate magnetometer for magnetic field measurements.
- MF/HF radio noise measurement instrument.
- Langmuir probe for plasma temperature measurements.
- Hyperspectral camera for lunar swirl measurement from close range.

The orbit of the satellite is designed to be a polar elliptical lunar orbit which would allow to scan the lunar surface over time and provide sufficient time for orbit adjustment with electrostatic sail.

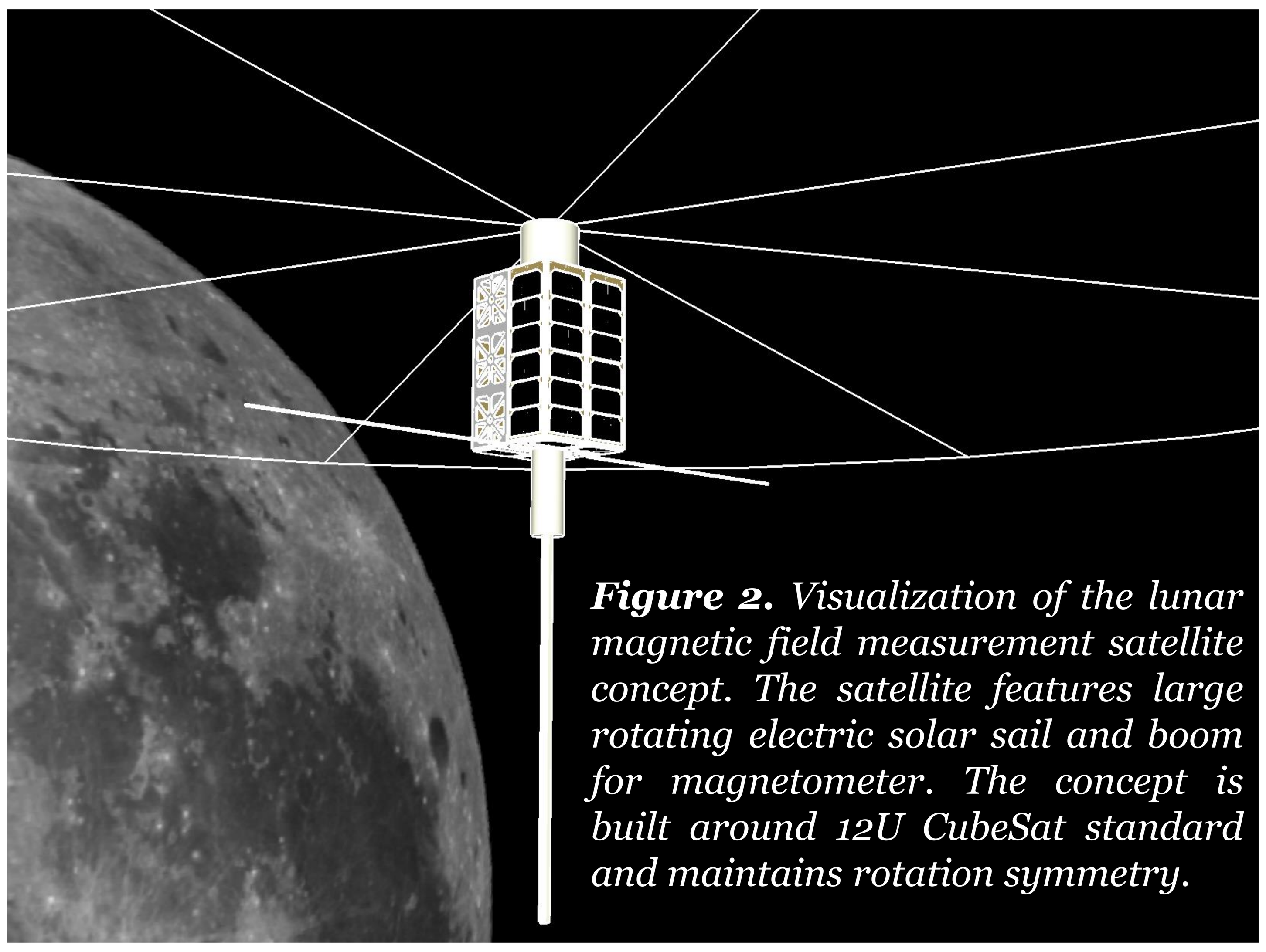

Figure 2. *Visualization of the lunar magnetic field measurement satellite concept. The satellite features large rotating electric solar sail and boom for magnetometer. The concept is built around 12U CubeSat standard and maintains rotation symmetry.*

Conclusions

The biggest challenge for a small satellite mission for lunar magnetic field measurement would be orbit control. Here we proposed to use electric solar wind sail, which would allow to control the orbit in solar wind by modulating tether voltages. In order to maintain good signal level in a very tiny satellite, very low orbit, few tens of kilometers, should be used. Additionally a very sensitive magnetic field sensor should be used in combination with various signal cleaning algorithms [4]. The plasma temperature and radio noise instruments complement help to describe the interaction with solar wind. The consortium behind this proposal has some experience on all proposed instruments on board CubeSat platform [5].

[1] Arkani-Hamed, J., & Boutin, D.: South Pole Aitken Basin Magnetic Anomalies: Evidence for the True Polar Wander of Moon and a Lunar Dynamo Reversal. Journal of Geophysical
Research: Planets, https://doi.org/10.1002/2016JE005234

[2] P. Janhunen, P. Toivanen, S. Merikallio, J. Polkko, E. Haeggström, H. Seppänen, R. Kurppa, J. Ukkonen, T. Ylitalo, S. Kiprich, et al. "Electric Solar Wind Sail Propulsion System Development". In: International Electric Propulsion Conference. 2011.

[3] Jarvinen, R., M. Alho, E. Kallio, P. Wurz, S. Barabash, and Y. Futaana, On vertical electric fields at lunar magnetic anomalies, Geophys. Res. Lett., 41, 2243–2249, doi:10.1002/2014GL059788, 2014.

[4] A. Riwanto, T. Tikka, A. Kestilä, and J. Praks. "Particle Swarm Optimization With Rotation Axis Fitting for Magnetometer Calibration". In: IEEE Transactions on Aerospace and Electronic Systems 53.2 (2017), pp. 1009– 1022. issn: 0018-9251. doi: 10.1109/TAES.2017.2667458

[5] Aalto University Satellite projects home page. http://satellites.aalto.fi

Aalto University
School of Electrical Engineering
Department of Electronics and Nanoengineering