OMOTENASHI Trajectory Analysis and Design: Landing Phase

Javier Hernando-Ayuso[1*] , Stefano Campagnola[2], Toshinori Ikenaga[2], Yusuke Ozawa[1], Bruno Sarli[2], Shota Takahashi[3], Chit Yam[2] and Tomohiro Yamaguchi[2]
[1]*The University of Tokyo, Japan;* [2] *JAXA, Japan;* [3]*Keio University, Japan*
javier.hernando@ac.jaxa.jp

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OMOTENASHI (Outstanding MOon exploration TEchnologies demonstrated by NAnoSemi-Hard Impactor) is a Japanese 6U cubesat which will be launched in 2018 by the American Space Launch System (SLS) Exploration Mission-1 (EM-1). SLS will deliver 13 cubesats, OMOTENASHI being one of them, into a lunar flyby orbit [1]. OMOTENASHI mission seeks to study the lunar radiation environment and soil mechanics using a nano-lander.
After detaching from SLS, OMOTENASHI must perform a series of maneuvers that will make this cubesat the first one to perform a semi-hard landing on the Moon. A first maneuver will put OMOTENASHI into a Moon-impacting orbit with a very shallow flight path angle at Moon arrival. After performing midcourse trajectory correction maneuvers if needed, a solid rocket engine will be ignited shortly before the expected collision with the Moon surface at a speed of approximately 2.5 km/s. After the braking maneuver, OMOTENASHI will experience a free-fall from a low altitude (close to 100 m) and arrive at the Moon surface with a speed of around 20 m/s [2].
In this paper we perform a detailed analysis of the landing phase and the DV2 maneuver. We study the subsystems performance and propose a deceleration strategy based on targeting a final altitude with zero vertical velocity. We consider uncertainties in the initial state (Orbit Determination - OD) and maneuver execution (attitude and propulsion) in order to assure the robustness of the trajectory. We find that the largest sensitivities come from the position, burn start time and total ΔV errors. These results suggest requirements to the propulsion subsystem and OD.
In particular, we are concerned about cases in which deviations from the nominal trajectory may cause OMOTENASHI to impact the surface during the rocket engine burn, causing mission failure. This is reflected in a trade-off between the final target height and the impact velocity: increasing the former reduces the number of early landings, but leads to a higher impact velocity. The latter has a direct effect on the requirements of energy dissipation devices of the lander.
A detailed Moon topography based on the SELENE mission data was used in this study to investigate the local terrain at the potential landing locations.

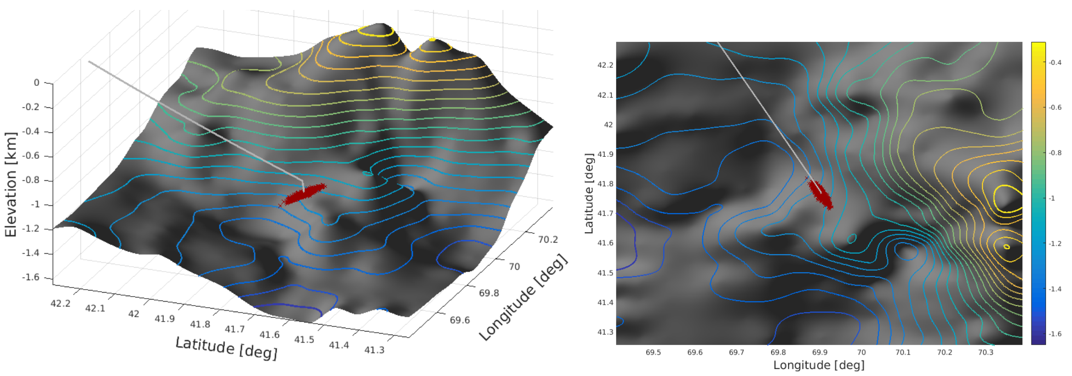

Fig. 1. OMOTENASHI landing dispersion with SELENE Moon topography. In the current nominal orbit, OMOTENASHI approaches the lunar surface from the North-west.

References

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