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DESIGN OF RETURN TRANSFERS FOR THE LUNAR POLAR SAMPLE RETURN MISSION

Abstract

Returning soil samples from the Lunar South Pole region has been of great interest by scientists for decades. The samples will allow determining the age of key events and lead to a better understanding of the history of our solar system. This paper presents the mission design for the proposed Lunar Polar Sample Return, which is currently a proposed joint mission between the European Space Agency (ESA) and the Russian Federation (ROSCOSMOS) with launch foreseen in 2024. This mission is composed of a lander and an orbiter that are launched separately. The lander arrives first at the moon and extracts the samples. It remains on the lunar surface for several days before lifting off and inserting into a low lunar polar orbit. A rendezvous strategy is then initiated for the orbiter to recover the sample canister from the lander. Finally the orbiter performs a trans-Earth insertion (TEI) burn to return to Earth and release the entry capsule in Kazakhstan a few days later.

An overview of the main phases of the mission is first discussed, which includes timeline and phasing strategy between the two spacecraft. One critical aspect lies in the strong requirements for the return leg to Earth, which makes this mission challenging and drives the overall design. The flight path angle at EIP is constrained by the entry corridor designed to cope with the EDL phase requirements. Moreover, landing over Kazakhstan requires that departures from the Moon are at periods of time when this is at lowest equatorial declination (thus one window of a few days each month). In addition, this needs to be performed between April and October to avoid snow cover and during the first three hours of daylight.

Some minimum-energy return transfer trajectories are investigated that meet the Earth re-entry conditions and comply with the mission requirements. An optimization problem is formulated from a low lunar polar orbit to the Earth surface. The return trajectories are generated in a high fidelity model considering third body perturbations as well as Earth oblateness. The effect of the main contingencies, such as delay in the ascent of the lander or delay in the TEI implementation are also analyzed. Some strategies to deal with those contingencies are explained and return solutions are proposed to assure returns to Earth that satisfy the arrival requirements even in case of delays.