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SIZING OF A PROPELLED-HOPPING SYSTEM ON THE MOON

Abstract

Many space agencies foresee the return of humankind to the Moon in this decade, establishing a permanent human outpost relying on in-situ resources and opening the gates of deep-space exploration for humans.

One of the envisioned locations for a human outpost are the lunar lava tubes. Those basaltic tunnels below the lunar surface are rich in materials and naturally shielded from radiation, micro-meteoroids and temperature excursion. However, before venturing inside the tubes with a human mission, it would be fundamental to assess the safety and map these underground caves leveraging a robotic mission.

This study aims to size a thrust-propelled hopping system on the Moon while also assessing its feasibility for the autonomous exploration and 3D mapping of the lava tubes. The hopping-thrusting capabilities would be helpful to overcome the lava tubes unknown terrain, as the system can perform small flights to avoid obstacles and navigate the lava tubes, reaching the areas farther from the entrance.

The sizing routine defines the hopping system's mass, power, thermal and data budget. Then the focus is shifted to the performances and capabilities of the Guidance, Navigation and Control (GNC) subsystem. The hopper relies on its optical payload to map and navigate the lava tubes. Therefore, a first mathematical model of the hopper has been developed to analyze the sensors needed for mapping and attitude control and their interactions with the control laws. Subsequently, the exploring and mapping scenario will be detailed with the control laws and path planning algorithms studied to solve them. The GNC system will allow the hopper to localize itself, compute its path, avoid obstacles and control its movement.

Therefore, the paper will first detail the system engineering study performed on the lava tube mission. Then, the mission's primary objectives, requirements, and concept of operations will be presented. Then the main trade-off at the subsystem level will be addressed. After, the main sizing rules for the hopper will be analyzed in detail. Eventually, an in-depth analysis of the GNC system will be proposed.