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ENCELADUS MOON IN SITU SCIENCE: PRELIMINARY MISSION ANALYSIS AND GNC DESIGN FOR THE EPOPEA MISSION

Abstract

Enceladus is one of the most scientifically interesting bodies in the Solar System. The presence of potential molecules for microbial life, as well as evidence of a large south polar sub-surface ocean of liquid water was revealed by the Cassini-Huygens mission. The Enceladus Plume and Ocean Prospecting for Exo-Astrobiology (EPOPEA) mission is a feasibility study carried out over three months at Politecnico di Milano to pursue a deeper insight into the moon's nature, featuring an Orbiter and a Lander. The mission analysis represents a critical driver while attacking such challenging mission design. Firstly, a multi-gravity assist strategy shall be exploited to keep bounded the overall interplanetary transfer cost. Then, the saturnian highly perturbed gravitational environment represents a major concern for station keeping and attitude control along the operational scientific orbit. Lastly, the surface uncertainties and the low gravity pose several challenges to the landing, specifically in view of the accuracy and safety requirements posed by the scientific objective of exploring the South Polar Region (SPR). The paper proposes a strategy to address the previously mentioned challenges altogether: gravity assists sequences for the heliocentric transfer, DSMs included, are optimised adopting a combined heuristic and local optimization approach. The study shows the feasibility of a transfer to Saturn with a cost of 786 m/s for the 14-year interplanetary leg, while considering constraints on the seasonal illumination of the SPR and the available launchers. A moon tour is then foreseen to reach Enceladus, selecting a strategy heavily driven by the related literature. Then, a Non-Keplerian Saturn-Enceladus Halo orbit is targeted to maximise the science output with multiple flythroughs in Enceladus' plumes and high-resolution imaging of the surface. That entailed the design of a fine-tuned Station-Keeping strategy, carried out by means of multiple shooting and numerical continuation techniques. An overall cost of 201 m/s is obtained over a 27-month mission lifetime. The landing trajectory is optimized through direct transcription and collocation method while its actual feasibility is ensured by the selected sensorssuite for attitude control, relative navigation, and hazard avoidance. Finally, a controlled impact with Tethys has been designed to answer the end-of-life disposal requirement, being compliant with Planetary Protection indications while granting flexibility in terms of mission operations. The paper will critically discuss the obtained

solution which successfully demonstrates the feasibility of a long-duration mission around Enceladus from a mission analysis point of view, building a solid baseline for more refined studies.