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ANALYSIS AND PRE-DESIGN OF A PASSIVE ENTRY VEHICLE AS KEY TO SMALL-SCALE SAMPLE RETURN MISSIONS

Abstract

Advances in system autonomy and propellant efficiency have enabled an era of robotic sample return missions. These missions allow terrestrial laboratories to analyze cosmic materials with unprecedented precision. As a consequence, missions like Stardust, Hayabusa, Hayabusa-2 and OSIRES-REx have revolutionized our view of the solar system. Until now, sample return missions have been major programs with cost ranging in the hundreds of millions of dollars. However, the last decade has seen unprecedented advances in miniaturization of space technology, giving rise to the small satellite ecosphere. Propagating this trend, mission concepts like the "Asteroid PrObe Sampler and Sample retUrn Mission (APOSSUM)" are developing small spacecraft that provide sample return capabilities for Near-Earth Object (NEO) exploration. A key technology for such mission concepts is the design of miniaturized and simplified sample return entry vehicles. To increase reliability and reduce mass and complexity, proposals for such systems are intended to be fully passive, replacing the parachute with an aerobraking maneuver from orbital velocity to a tolerable impact speed. Although missions based on small spacecraft concepts particularly benefit from such an approach, the added reliability and high payload mass fraction of the vehicle additionally make this approach desirable for major science programs, such as Mars Sample Return. However, the requirement of a braking maneuver through the entire velocity regime from hypersonic to subsonic velocities ties mission success to a fundamental question in applied aerodynamics, concerning dynamic stability, particularly in the transonic domain. These regimes are governed by widely varying aerodynamic effects, which set strict requirements on the vehicle shape, while still demanding robustness to thermal and structural loads in a small-scale design. This paper and presentation will focus on system-level considerations and identification of an outer mold line for a vehicle that fulfills these requirements. The experimental work builds upon findings of a parametric free-flight study conducted in DLR's vertical facility VMK to identify backshell influences on dynamic stability and measurements in the hypersonic facility H2K, investigating the influence of frontshell parameters to define an outer mold line. Investigations considering structural loads and aerothermal heating are conducted analytically. All investigations are based on conditions at entry interfaces which are derived from a variety of NEO return trajectories, making the system applicable to a wider array of missions. The APOSSUM proposal continues development on the down selected options, positioning them as viable candidates for ESA's ongoing F3 call and future small body exploration missions.