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VESPUCCI MISSION: UNVEILING COMETARY SECRETS VIA DRILLING AND CRYOGENIC SAMPLE RETURN

Abstract

VESPUCCI (Versatile Explorer for Sampling Purposes, Unveiling and Collecting Cometary Ice) is a pre-phase A mission study aimed at returning at least 100g of icy samples in a pristine state from a depth of >1 m from comet 62P/Tsuchinshan; the mission will reveal key information on the solar system's formation process. With respect to previous relevant studies on the topic, especially based on touch-and-go strategies, the VESPUCCI mission would include an Orbiter and a Lander equipped with a drilling mechanism: that ensures higher scientific return, paid in larger expected costs, mass and complexity. Technology status for collection and storage of cryogenic samples, for which relevant progress in the near future is expected, is the primary mission driver; this paper discusses challenges and criticalities raised by the preliminary mission design and states its feasibility for further refinements.

Initially, a survey is undertaken to assess the trajectory feasibility of scientifically relevant short-period comets, resulting in the selection of comet 62P/Tsuchinshan, along with a contingency comet option that permits a 1.5-year mission delay, whilst retaining the baseline design. Scheduled for lift-off in 2039 onboard an Ariane 64 and with a mission lifetime of 20 years, VESPUCCI will intercept the comet after its perihelion passage in 2049, initiating a seven-month-long in-situ operations period. This would allow its progressive characterisation, from extensive nucleus mapping to the selection of candidate landing sites, building upon the strategies pioneered by previous missions, notably ESA-Rosetta. After the Lander's separation and its descent towards the comet's surface, sampling operations start. During surface operations, the Orbiter keeps fulfilling the mapping requirements, while simultaneously serving as a communication relay. Collected samples would be stored in a canister and transferred to the Orbiter through an Ascent Vehicle detaching from the Lander, drawing from the strategy employed in the Mars Sample Return mission. The sample container, featuring an actively cooled storage system, phase change materials, and aerogel insulation, prevents the amorphous alteration of water ice during the return leg and ensures robustness upon ground retrieval following the Sample Return Capsule (SRC) re-entry.

The final design predicts a 5.4-ton system (wet), with dry mass allocations of 2.3-tons to the Orbiter, 237 kg to the Lander, and 171 kg to the SRC. This paper outlines the mission analysis, operational concepts, and subsystem specifications, emphasising the primary challenges that must be addressed from both a technological development and operational perspective to achieve the mission objectives.