ABSTRACT
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Small Landers and Separable Sub-Spacecraft for Near-term Solar Sails

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Abstract

Following the successful PHILAE landing on comet 67P/Churyumov-Gerasimenko with ESA's ROSETTA probe and the launch of the MINERVA rovers and the first Mobile Asteroid Surface Scout, MASCOT, aboard the JAXA space probe, HAYABUSA2, to asteroid (162173) Ryugu, surface science packages in the form of independent small spacecraft have become a topic of increasing interest. Both were integrated at the instrument level in their respective mothership for applications related to small solar system bodies. Their unique combination of efficient capabilities, resource-friendly design and inherent robustness makes them attractive as a mission element for exploration missions.

We discuss advantages and constraints of small sub-spacecraft for planetary science and technical applications, focusing on emerging areas of activity such as asteroid diversity studies by multiple rendezvous, planetary defence, and asteroid mining, on the background of our projects. These include PHILAE; MASCOT; MASCOT2, a long-term stationary lander for Didymoon with ESA's AIM spacecraft, part of the joint U.S.-European Asteroid Impact Deflection Assessment (AIDA) mission; a Jupiter Trojan asteroid lander studied for the JAXA Solar Power Sail mission, and others. The GOSSAMER-1 solar sail deployment concept also involved independent sub-spacecraft operating synchronized to deploy the sail and then undock to lighten the sailcraft.

Small spacecraft require big changes in the way we do things and occasionally a little more effort than would be anticipated based on a traditional large spacecraft approach. The operators' requirements for cutting-edge missions compatible with available launch capabilities impose significant constraints in resources, timelines, timeliness, mass and size. Re-use requirements stipulate a broad range of equipment maturity levels from fresh concepts to off-the-shelf units. The resulting Constraints-Driven Engineering environment has led to new methods which transcend traditional evenly-paced and sequential development. We evolved and extended Concurrent Design and Engineering (CD/CE) methods originally incepted for intitial studies into Concurrent Assembly, Integration and Verification (CAIV) applied to maintain parallel tracks of integration and test campaigns. Model-Based Systems Engineering (MBSE) supports design trades and constant configuration evolution due to unforeseen changes and optimization across interface boundaries in MBSE-aided CAIV.

Solar sails are much more likely to be small spacecraft themselves in terms of their launch configuration, especially in the near-term. From the ESA/ESTEC GOSSAMER Roadmap Science Working Group studies and the experience gained in the small landers PHILAE and MASCOT, we expect that near-term sails, particularly of the GOSSAMER concept, will harmonize well with separable instrument payload packages in several mission types.