Small Spacecraft for Small Solar System Body Science, Planetary Defence and Applications

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Abstract

The recent successful landings and re-awakenings of PHILAE, the lander carried aboard ROSETTA to comet 67P/Churyumov-Gerasimenko, and the launch of the Mobile Asteroid Surface Scout, MASCOT, aboard the HAYABUSA2 space probe to asteroid (162173) Ryugu have highlighted the capabilities, potential and robustness of small spacecraft as a mission element in the exploration of small solar system bodies.

Programmatics and science communities' demand for cutting-edge missions combined with available launch capabilities set significant constraints in resources, timelines, timeliness, mass and size. The initial design faces a broad range of maturity from fresh concepts to off-the-shelf units. Challenges in this Constraints-Driven Engineering environment have lead to new methods which transcend traditional evenly-paced and sequential development. Concurrent Design and Engineering (CD/CE) incepted for intitial studies has been evolved into Concurrent Assembly, Integration and Verification and applied in all phases in some of our projects to achieve convergence of asynchronous subsystem maturity timelines and match parallel tracks of integration and test campaigns. When integrating units of widely diverging maturity into consistent systems under wide-ranging re-use requirements Model-Based Systems Engineering supports design trades

and configuration evolution due to unforeseen changes. Positive change can result from system-level CD/CE optimization across interface boundaries.

We discuss advantages and constraints of small spacecraft for planetary science and its applications focusing on planetary defence, looking at our projects:

PHILAE arrived at its intended landing site, Agilkia, on 67P on November 12th, 2014, but due to anchoring failures bounced for two hours to settle at the shadowed site Abydos. It successfully conducted its primary mission until energy was depleted. Telemetry was received sporadically again from June on, indicating intermittent activity since May.

Within 3 years, a cooperation of DLR with CNES, JAXA and several university institutes developed MASCOT which carries four full-scale science instruments to the surface of Ryugu and provides relocation capability. The shoebox-sized, <10 kg landing module is an organically integrated high-density design spacecraft. The JAXA sample-return space probe HAYABUSA2 carrying MASCOT, when compared to ROSETTA/PHILAE by its size it could already be considered a small spacecraft, but it is more so by project timeline, philosophy and design re-use of the spectacular HAYABUSA mission.

Currently in test preparation is the GOSSAMER-1 solar sail ground deployment demostrator qualification model, originally the first step in the DLR-ESTEC GOSSAMER roadmap for solar sailing enabling unique science missions that are presently infeasible using other post-launch propulsion. Its heritage will now be used to advance lightweight large-scale photovoltaic generators.

We present the advanced design, integration and testing methods required by fast-paced highly optimized small spacecraft projects. We show why small spacecraft require big changes in the way we do things and sometimes more effort than would be anticipated based on a traditional large spacecraft approach. As an outlook, we illustrate how tailored concurrent methods could also benefit ‘large’ spacecraft and traditional methods minded spacecraft customers, and why the combination of lightweight sail and small lander can become the key to most solar system bodies currently out of reach, for planetary defence and science.