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FLIGHTS ARE TEN A SAIL – RE-USE AND COMMONALITY IN THE DESIGN AND SYSTEM ENGINEERING OF SMALL SPACECRAFT SOLAR SAIL MISSIONS WITH MODULAR HARDWARE FOR RESPONSIVE AND ADAPTIVE EXPLORATION

Abstract

The exploration of small solar system bodies started with fast fly-bys of opportunity on the sidelines of missions to the planets. The tiny new worlds seen turned out to be so intriguing and different from all else (and each other) that dedicated sample-return and in-situ analysis missions were developed and launched. Through these, highly efficient low-thrust propulsion expanded from commercial use into mainstream and flagship science missions, there in combination with gravity assists. In parallel, the growth of small spacecraft solutions accelerated in numbers as well as individual spacecraft capabilities. The on-going missions OSIRIS-REx (NASA) or Hayabusa2 (JAXA) with its landers MINERVA-II and MASCOT, and the upcoming NEAscout mission are examples of this synergy of trends. The continuation of these and other related devlopments towards a propellant-less and highly efficient class of spacecraft for solar system exploration emerges in the form of small spacecraft solar sails designed for carefree handling and equipped with carried landers and application modules. These address the needs of all asteroid user communities – planetary science, planetary defence, and in-situ resource utilization – as well as other fields of solar system science and applications such as space weather warning and solar observations. Already the DLR-ESTEC GOSSAMER Roadmap for Solar Sailing initiated studies of missions uniquely feasible with solar sails such as Displaced L1 (DL1) space weather advance warning and monitoring and Solar Polar Orbiter (SPO) delivery, which demonstrate the capabilities of near-term solar sails to reach any kind of orbit in the inner solar system. This enables Multiple Near-Earth Asteroid (NEA) rendezvous missions (MNR), from Earth-coorbital to extremely inclined and even retrograde target orbits. For these mission types using separable payloads, design concepts can be derived from the separable Boom Sail Deployment Units characteristic of DLR GOSSAMER solar sail technology, nanolanders like MASCOT, or microlanders like the JAXA-DLR Jupiter Trojan Asteroid Lander for the OKEANOS mission which can shuttle from the sail to the targets visited and enable multiple NEA sample-return missions. These nanospacecraft scale components are an ideal match creating solar sails in micro-spacecraft format whose launch configurations are compatible with secondary payload platforms such as ESPA and ASAP. The DLR GOSSAMER solar sail technology builds on the experience gained in the development of deployable membrane structures leading up to the successful ground deployment test of a (20 m) solar sail at DLR Cologne in 1999 and in the 20 years since.