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II. Asteroid Surrounding Environment

ABSTRACT

Small Spacecraft Solar Sail Missions for Multiple Near-Earth Object Prospection: Remote Sensing, In-Situ Characterization and Sample Return

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Solar sail technology has been developed by the German Aerospace Center (DLR) since the 1990s, culminating in a successful (20 m)² sail ground demonstrator deployment test in 1999 at DLR Cologne. In the last years a further development of the technology for controlled deployment of gossamer spacecraft was made in the DLR Gossamer-1 Project.

The DLR-ESTEC Gossamer roadmap originally envisaged the extremely fast-paced development of solar sailing technology by a series of successively leapfrogging low-cost demonstrator flights leading towards the technological basis for first science missions. In this framework, the Gossamer-1 deployment demonstrator for a (5 m)² sail structure in low Earth orbit dominated by drag was to be followed by the (20 m)² sail effect and attitude control demonstrator Gossamer-2 for higher Earth orbits dominated by solar radiation pressure, and the (50 m)² Gossamer-3 sailcraft proving the principle within the Earth-Moon system. It was to demonstrate sufficient trajectory and attitude control for science missions using a simple lightweight camera for timed pointing and localization reference imaging and a magnetometer to study the space environment around a sail. Since the first Roadmap studies, the expected payload capability increased from a few to several kg.

Three scientific mission types which are exclusively feasible with the unique capabilities of solar sail propulsion were identified and studied in detail by science working groups as candidates for a first science mission. These studies were based on the expected performance of solar sail technology developed in the Roadmap. Each mission was to be completed within 10 years:

- Multiple Near-Earth Asteroids (NEA) Rendezvous (MNR) & station-keeping, with optional Near-Earth Object (NEO) fly-bys of opportunity,
- Displaced Lagrange point 1 (DL_1) solar storm early warning at twice L_1 distance from Earth,

- Solar Polar Orbiters (SPO) for solar wind and coronal research and/or spectroscopic imaging of the Sun.

For MNR, trajectories for several triple-rendezvous missions were calculated assuming near-term 1st-generation sailcraft performance. Notably, a solar sail based mission can change target NEAs *in flight* whenever new knowledge triggers a change of interest. The science payload of 12 kg included a multispectral imager, a vis-NIR point spectrometer, an IR radiometer, and three 1U-CubeSat-sized drop probes. The spacecraft was expected to fit a standard ESPA or ASAP ‘micro’ piggy-back payload launch envelope. The ‘mini’-class ENEAS missions with launch masses from 150 to 750 kg studied a decade earlier based on similar sail performance estimates include single- and triple-sample-return mission profiles. Sailcraft with a performance between MNR and ENEAS could carry a single MASCOT-type or several CubeSat-like landers to each rendezvous target. Sharing of the science payload between lander and sailcraft may be feasible for missions focusing more on a single target.

With the technology available already now, it would be possible to develop a lightweight solar sail that fulfills the mission requirements of a 10-year multiple NEO rendezvous mission, thereby providing the means to study, prospect, or even deflect such potentially mineable or dangerous objects. In recent years, DLR has gained significant experience in realizing small spacecraft based projects on very short timelines with a high degree of strategic re-use of proven components between projects such as MASCOT and its successors, Gossamer-1, ROBEX, the ADEO dragsail, the Gossamer successor project GoSolAr for very large scale photovoltaics, and others. Also, the infrastructure has been expanded to include facilities for functional and qualification testing, and the study and testing of critical effects of the space environment on new types of structures such as sail foils and thin-film photovoltaics.

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