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RESPONSIVE EXPLORATION AND ASTEROID CHARACTERISATION THROUGH INTEGRATED SOLAR SAIL AND LANDER DEVELOPMENT USING SMALL SPACECRAFT TECHNOLOGIES

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ABSTRACT

In parallel to the evolution of the Planetary Defense Conference, the exploration of small solar system bodies has advanced from fast fly-bys on the sidelines of missions to the planets to the implementation of dedicated sample-return and in-situ analysis missions. Spacecraft of all sizes have landed, touch-and-go sampled, been gently beached, or impacted at hypervlocity on asteroid and comet surfaces. More have flown by close enough to image their surfaces in detail or sample their immediate environment, often as part of an extended or re-purposed mission. And finally, full-scale planetary defense experiment missions are in the making. Highly efficient low-thrust propulsion is increasingly applied beyond commercial use also in mainstream and flagship science missions, in combination with gravity assist propulsion. Another development in the same years is the growth of small spacecraft solutions, not in size but in numbers and individual capabilities. The on-going NASA OSIRIS-REx and JAXA HAYABUSA2 missions exemplify the trend as well as the upcoming NEASCOUT mission or the landers MINERVA-II and MASCOT recently deployed on Ryugu.

We outline likely as well as possible and efficient routes of continuation of all these devlopments towards a propellant-less and highly efficient class of spacecraft for small solar system body exploration: small spacecraft solar sails designed for carefree handling and equipped with carried landers and application modules, for all asteroid user communities – planetary science, planetary defence, and in-situ resource utilization.

This projection builds on the experience gained in the development of deployable membrane structures leading up to the successful ground deployment test of a (20 m)² solar sail at DLR Cologne and in the 20 years since. It draws on the background of extensive trajectory optimization studies, the qualified technology of the DLR GOSSAMER-1 deployment demonstrator, and the MASCOT asteroid lander. These enable 'now-term' as well as near-term hardware solutions, and thus responsive fast-paced development. Mission types directly applicable to planetary defense include: single and Multiple NEA Rendezvous ((M)NR) for mitigation precursor, target monitoring and deflection follow-up tasks; sail-propelled head-on retrograde kinetic impactors (RKI) for mitigation; and deployable membrane based methods to modify the asteroid's properties or interact with it.

The DLR-ESTEC GOSSAMER Roadmap 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 capability of near-term solar sails to achieve NEA rendezvous in any kind of orbit, from Earth-coorbital to extremely inclined and even retrograde orbits. For those mission types using separable payloads, such as SPO, (M)NR and RKI, 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 asteroids visited and enable multiple NEA sample-return missions. These are an ideal match for solar sails in micro-spacecraft format whose launch configurations are compatible with ESPA and ASAP secondary payload platforms.

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