PDC2015
Frascati, Roma, Italy

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IAA-PDC-15-P-20

Large Lightweight Deployable Structures for Planetary Defence: Solar Sail Propulsion, Solar Concentrator Payloads, Large-scale Photovoltaic Power

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Keywords: *solar sail, solar concentrator, large photovoltaic array, GOSSAMER roadmap, gravity tractor*

ABSTRACT

In the past, several planetary defence (PD) related mission types have been proposed that use very large spacecraft near the target small solar system body (SSSB), while in cruise towards it, or during both phases. Examples are missions using solar sail propulsion, very large photovoltaic generators, or solar concentrator mirrors for SSSB deflection.
However, for Earth escape, the largest currently available launch vehicles are constrained to about 10 t payload mass per launch. The largest payload fairings have about 250 m³ volume. Requirements for higher initial velocity would further constrain the payload. Docking of spacecraft on a common trajectory may be feasible but available technologies were developed for crewed spaceflight. This equipment is designed for large man-rated pressurized spacecraft and thus heavy, with or without fuel transfer options. Such scenarios may require Earth parking orbital phases, new escape stages with extended high-performance fuel storage, or a significant expansion of rendezvous navigation technologies to deep space beyond the Apollo-era low lunar orbit experience.
Planetary defence related missions of this size are only likely to be built upon discovery of a specific threat. Consequently, there is a strong motivation for single-launch spacecraft even in overall multiple-launch scenarios. Hence, for practical

interplanetary missions, very large structures need to be very lightweight *and* deployable with a very high volumetric compression factor.

The GOSSAMER solar sail technology developed by DLR since the 1990s and subsequently extended to the framework of the DLR-ESTEC GOSSAMER solar sail technology roadmap has created tested boom and foil structures deployment mechanisms with a focus on solar sail applications. They also appear suitable as a technology base for the development of other very large lightweight deployable structures. Some interplanetary science missions benefiting from the unique capabilities of solar sail propulsion have been studied. Based on GOSSAMER technology, they include multiple NEO rendezvous and fly-by, near-Earth co-orbital, and high ecliptic inclination scenarios.

Degradation studies, both theoretical and experimental, of thin films used in solar sail propulsion technology are performed at DLR-Bremen. By use of the DLR's Complex Irradiation Facility the most important degradation factors can be simulated, i.e. flux of protons, electrons and a wide range of electromagnetic radiation, from 40 to 2500 nm. Films exposure can be made simultaneously with all working sources; hence, a wide range of degradation effects can be simulated.

An overview of the state of the GOSSAMER solar sail deployment technologies developed and tested so far is presented. An outline of their potential for highly compressed deployable photovoltaic arrays and foil-based solar concentrator mirrors will be given.

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