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Perspectives of Electric Propulsion for Outer Planetary and Deep Space Missions

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Abstract

Solar-electric propulsion (SEP) is superior with respect to payload capacity, flight time and flexible launch window to the conventional interplanetary transfer method using chemical propulsion combined with gravity assists. This fact results from the large exhaust velocities of electric low–thrust propulsion and is favourable also for missions to the giant planets, Kuiper-belt objects and even for a heliopause probe (IHP) as shown in three studies by the authors funded by DLR. They dealt with a lander for Europa and a sample return mission from a mainbelt asteroid [1], with the TANDEM mission [2]; the third recent one investigates electric propulsion for the transfer to the edge of the solar system.

All studies are based on triple-junction solar arrays, on rf-ion thrusters of the qualified RIT-22 type and they use the intelligent trajectory optimization program InTrance [3].

Mission analysis

As electric propulsion scenario for an Europa lander this paper will present at first a two-stage scheme with 33 kW BOM solar power: Up two a solar distance of about 3 AU three ion thrusters with high specific impulse of 6500 s will run. This stage will be jettisoned and two ion thrusters with low specific impulse of 3700 s will continue the transfer to Jupiter and spiral the spacecraft into a parking orbit of 80 R_J. While spiralling down, the magnetosphere of Jupiter can be mapped. The lander will be a transported by a chemical 675 kg stage released from the parking orbit, passing Ganymed. The total launch mass and the total mission duration resulted in 2.71 tons and 5.7 yrs, respectively.

With respect to the selection of Laplace as a combination of NASA and ESA missions, the authors intend to investigate the trade-off for reducing the transfer duration by the installation of three ion thrusters in ESA´s JGO. These engines might use the solar power from the arrays while this power is not needed otherwise.

The investigation of a sample return mission from "19, Fortuna" was based on the application of SEP for both transfer legs. Three ion engines with 4700 s of specific impulse would need a BOM solar power of 17.3 kW. Launch mass and total mission duration resulted in 1.56 tons and 5.7 yrs, respectively [4].

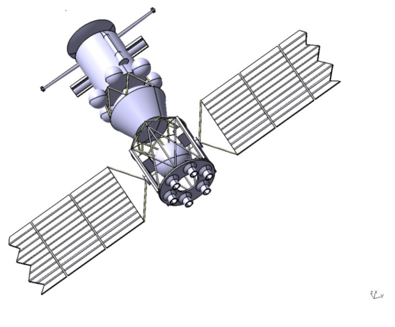

Fig.1: TANDEM-double probe with SEP – stage, aeroprobe and chemically propelled orbiter on top

For a SEP based interplanetary transfer to Saturn using an Ariane-5 launcher, we assumed a TANDEM oriented spacecraft (orbiter and aeroprobe) with a mass of 2.96 tons as payload for the SEP stage. This consists of 6 ion engines running with a specific impulse of 7400s. Supplying 79 kW of BOM solar power the transfer to Saturn is possible within 6.6 yrs. Fig. 1 displays a spacecraft version equipped for SOI-aerocapture and chemical TOI while fig.2

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reproduces a calculated trajectory excluding any gravity assist.

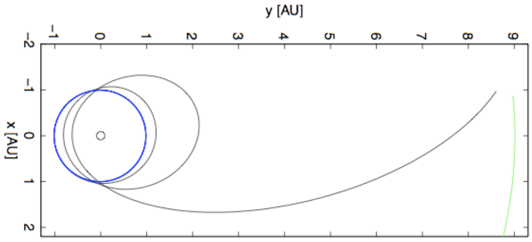

Fig.2: Trajectory to Saturn SOI with 6.6.yrs flight time

The presently examined mission to the edge of the solar system assumes a mass of 250 kg for the IHP-probe, to be propelled by SEP to a solar distance of about 200 AU within less then 20 yrs. First trajectory calculations show the feasibility of the application of electric propulsion for this very demanding mission requiring an extreme velocity increment value Δv. Contrary to chemical propulsion, the SEP-approach fulfills the agencies´ mission requirements. Compared with solar sailing and nuclear-electric propulsion, SEP represents a state-of-the-art method.

The paper will describe basic features of solar-electric propulsion, physical parameters of the propulsion components and give selected details for the investigated missions mentioned above.

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