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Asteroid touring mission with Electric Solar Wind Sail

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Abstract

Current and planned asteroid missions target only a single, or a few of asteroids, and have consumed their propellant after reaching their targets. We propose here using the new Electric Solar Wind Sail (E-sail) technology in a mission touring several different asteroids with the same spacecraft. This is made possible by the fact that E-sail does not consume any propellant and that the E-sail is well manoeuvrable. Moreover, most of the asteroids reside at a convenient distance from the Sun, providing the E-sail with a sufficient stream of solar wind particles to draw momentum from. Currently E-sail seems to be a superior propulsion method for asteroid touring mission type of tasks discussed in this paper.

1. Technology

When 2000 km of conductive tether is charged up to about 20 kV and flown perpendicular to the solar wind at 1 AU distance from the Sun, the tether will experience a push of 1 N. This push is almost solely due to the solar wind protons which, while moving at the same solar wind speed of around 400 km/s, weight 2000 times more than electrons. To keep this huge length of tethers (equal to the distance from Helsinki to Paris) in shape, it could be divided, for example, into hundred 20 km pieces. These tether strips could then be brought together at one end and the structure pushed into rotation in a wheel-like motion around this central knot at the frequency of about once in an hour. Now the centrifugal acceleration will keep the tethers stretched.

Solar wind however, is not a stable stream, but has lots of variations that would, if left uncontrolled, lead neighboring tethers to having different rotational speeds causing inevitable collisions and knotting. Introducing flexible auxiliary tethers to connect the other ends of the main tethers will stabilize the system so that no active steering of single tethers will be necessary. It looks like the auxiliary tethers are forming a rim of a wheel on which the main tethers form the spokes. Given the mechanical stability of such a sail structure, the sailcraft can then be accurately navigated even when the solar wind variations are considered [1]. The whole structure can be manufactured to weigh less than 100 kg.

This construction is called the Electric Solar Wind Sail, or E-sail for short [2, 3]. The E-sail does not consume propellant; it only needs couple of square meters of solar panels to keep its tethers charged and small traditional thrusters to initiate and possibly also to sustain its rotational movement. The E-sail technology is currently being developed into working prototypes by the European Union's Seventh Framework Programme for Research and Technological Development, EU FP7. The project is named ESAIL (**http://www.electric-sailing.fi/fp7**). [4]

The advantages of a small, but constant acceleration are huge for asteroid touring type of missions. Besides being able to change its course at any time of

its mission, the lifetime integrated impulse far exceeds those acquirable with traditional means. For example, on a ten year mission an E-sail producing 1 N of push can produce 300 MNs of total-impulse, I_{tot}. The same could be achieved with 100 000 tons of chemical propellant. If our E-sail would be propelling a 1000 kg spacecraft, the accumulated velocity change, ΔV, over the ten year mission would be astounding 300 km/s. A corresponding feat with an ion engine would require Isp of 30 000 s and power of around 200 kW. But as current solar power technology is capable of producing only around 100 W/kg, this would lead to solar panels weighing 2000 kg, which is 20 times more than the E-sail. There is thus a great promise in the E-sailing technology, which is why it should be developed into a full-scale solar wind test mission without any delay.

2. Asteroid touring

There are several Near Earth Asteroids (NEA), not to mention the asteroid belt between the orbits of Mars and Jupiter, where there are an estimated one to two million asteroids of diameter over 1 km. Besides scientific interest, utilization of the materials mined on asteroids would enable development of larger scale space infrastructure. Raw materials from asteroids could be used in taking the huge space based solar power structures into orbit, and maybe later also as structural building materials for various purposes. Some mined products found on asteroids could also be valuable down on Earth. Platinum group metals, for example, could enable large scale use of fuel cell technologies on Earth. In addition to touring missions E-sail could play a role of a cargo carrier, as it could, with low cost and high efficacy, move back and forth between asteroids and Earth.

A mission flying into asteroid belt and having the opportunity to hop from the vicinity of one asteroid to the other at will, would have huge advantage over current “fly-by a couple” or “land on the chosen one” – missions. Scientists and miners could have a closer look at several targets and they could decide the next target and the duration of investigations once at the vicinity of the asteroid, so the operations would be very flexible. Such a mission could characterize and map several asteroids, some with rapid fly-bys and a few chosen ones during lengthier rendezvous.

It might be good to start with NEAs. Closer distances to Earth make communications easier and mission durations shorter; this is why NEAs would also be more tempting for mining industry. Moreover, NEAs are most likely to cause impact threat with Earth, which is why we should develop techniques to reach and influence their orbits. E-sail has previously been proposed for the job [5].

3. Summary and discussions

Electric Solar Wind Sail is a novel technique enabling new kinds of space missions. E-sail could be used for skipping from one asteroid to another in an asteroid touring mission. As the E-sail provides steerable thrust without propellant consumption, it could choose its targets as it goes. Mission planning could thus be changed fast, if other more interesting targets were discovered.

There is a great promise in the E-sailing technology. It could allow a new kind of fast and effective space travel independent of launch windows and fuel gauges. E-sail technology should thus be developed into a full-scale solar wind test mission without delay.

References

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