CubeSat Deorbit Device based on combination of gravity gradient tape, aerodynamic drag, electrodynamic tether and ion engine

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A proposed method of CubeSat de-orbiting is to use four inflatable double-layer thin-film balloons, drag tether with end mass in form of a panel and ion engine.
The balloons increase the body's area to mass ratio and shortening orbital lifetime (Figure 1). In addition balloons have a metal coating on its surface and there is an excess charge. The balloons are electromagnetic tether and use of magnetic effect to increase the rate of de-orbiting. Charged balloons moves with at high velocity through a Earth magnetic or electric field and experiences a magnetic force. Material for the balloon is aluminized boPET (biaxially-oriented polyethylene terephthalate) films. It is used of sublimating benzoic acid to inflate balloons.

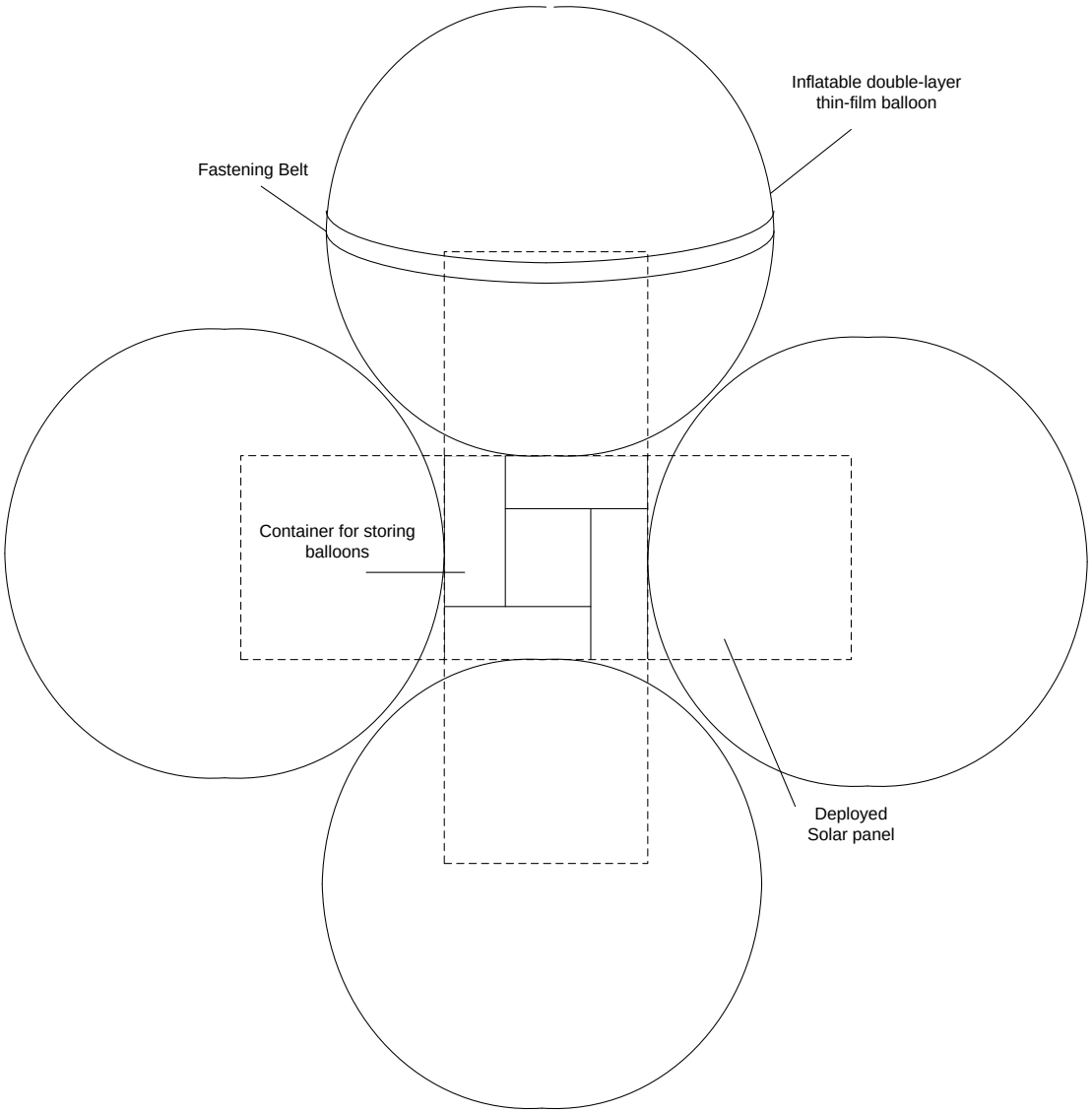

Figure 1. Inflatable double-layer thin-film balloons. View from above. Drag tether does not be shown.

The end mass in form of a panel a body connected to the spacecraft by four long thin optical fibers is drag tether (Figure 2). The tether is kept in position by gravity gradient forces and is on the Earth-facing side of the spacecraft. Its make use of drag to slow the spacecraft down, decreasing its orbital energy, and lowering its altitude.

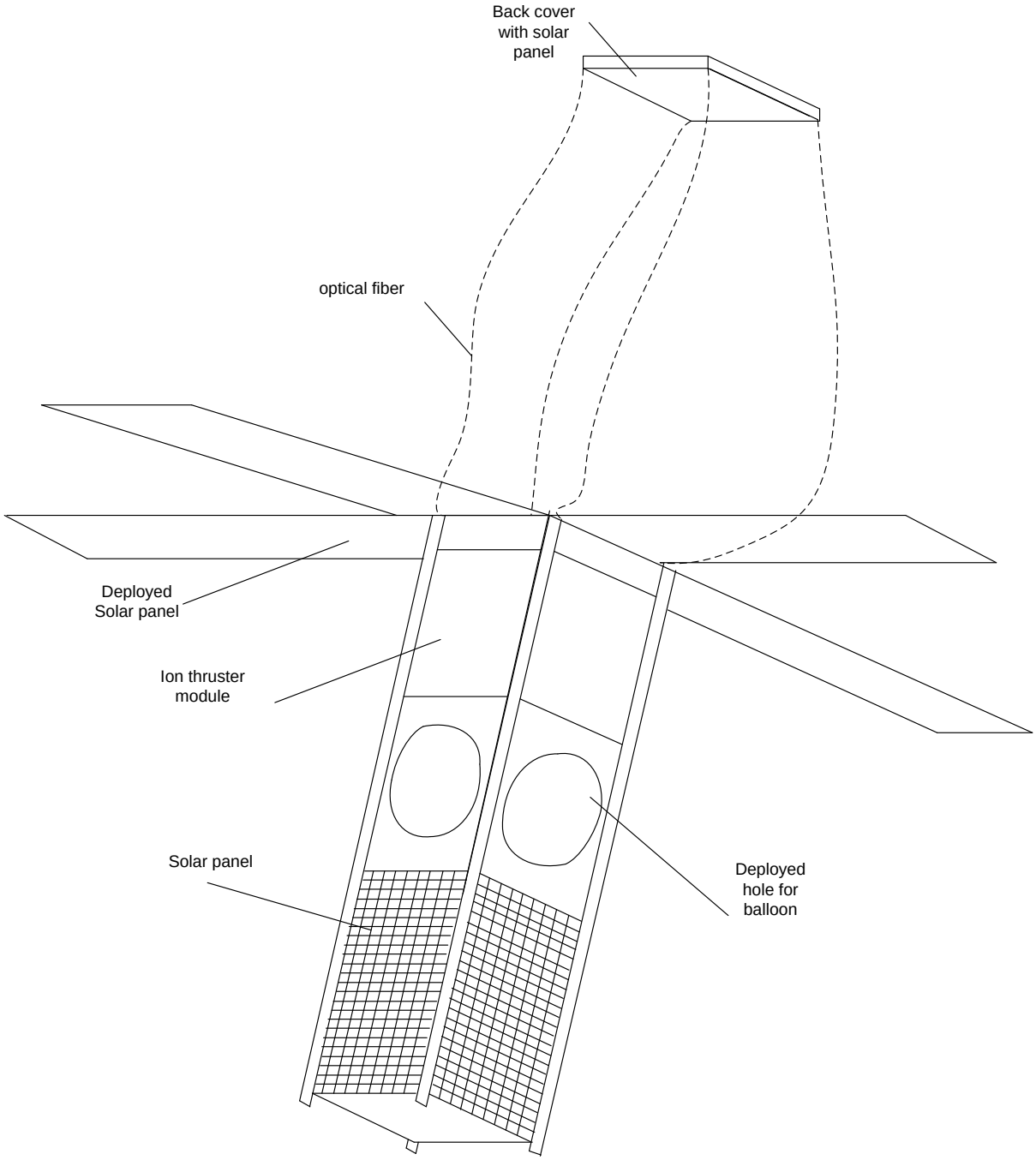

Figure 2. End mass in form of a panel connected to the spacecraft by four long thin optical fibers is drag tether. Balloons do not be shown.

If the initial orbit is around 600 km to go into orbit, which is 400 km below (which cling to the air), it is necessary to slow down by about 2%. From the Kepler law and the energy conservation law it is necessary to pay off 2 000 000 joules of energy (200 kgm / s of impulse).

On the altitude of 600 km length of the free path of the molecules is of 10 km, which corresponds to a concentration of $1/10000/10^{-19} = 10^{15}$ m^{-1}. The air pressure at this location is 10^{15} 10^{-23} $1000 = 10^{-5}$ Pa.

When you sail 1 m^2 the speed damping it will take at least 0.5 years. The lifetime of the device without the sails is 100 times longer. Estimated data of deorbiting are represented on the Figure 3, 4.

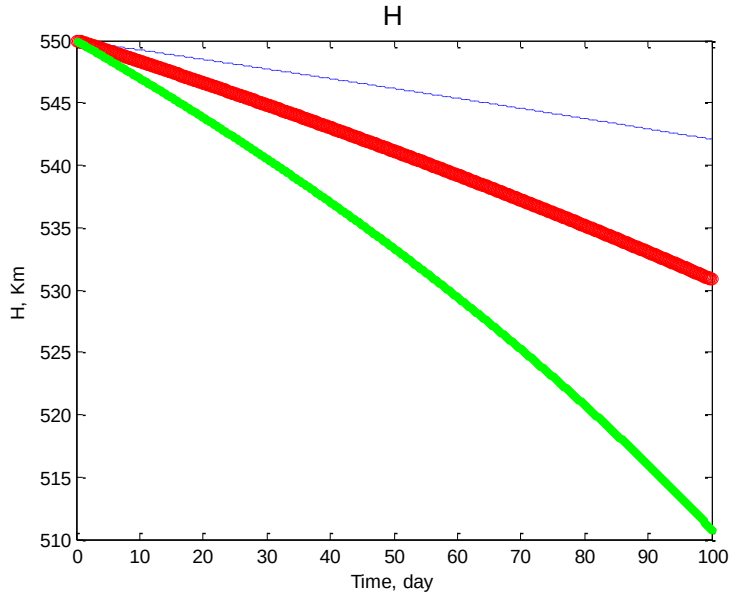

Figure 3. Rough estimation deorbiting under R = 0.1 (blue), 0.15 (red), 0.2 (green) m

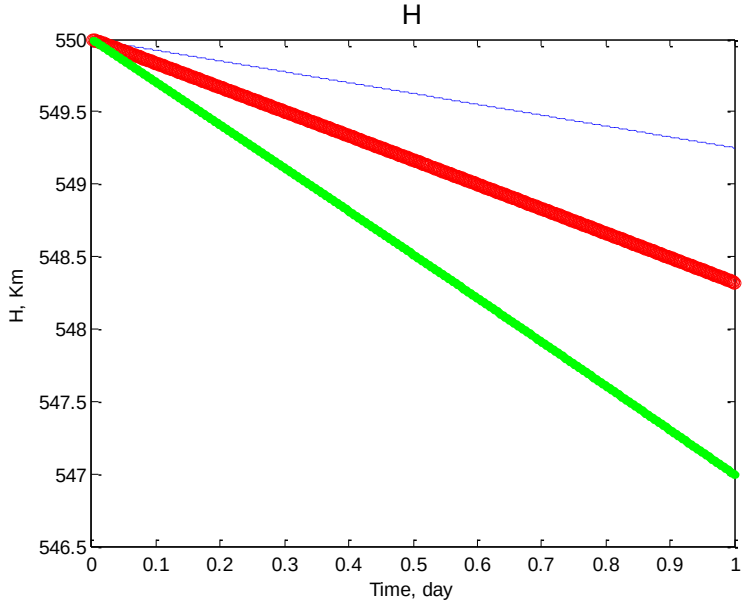

Figure 4. Improved (smaller step) estimation deorbiting under R = 0.1 (blue), 0.15 (red), 0.2 (green) m

The use of a solar wind is less practical. Proton concentration is about 1 000 000 m^{-1}. That is, about 10 million longer.

And the last but not the least system – ion thruster module. Balloon with 0.2 kg of gas namely ammonia or hydrazine can be accelerated using the ion engine to 10 - 100km / s will have impulse and 2 10^3. Impulse of the satellite is about 10^5. This is enough to de-orbit. Obviously, this will need 2 10^7 joule of electric power. So if you afford to spend 1W, the process will take six months. Naturally for such a system engine impulse orientation in apogee and perigee will be very significant. Stabilization and orientation system (passive/active electromagnetic) of such a satellite will be paid much attention because it is obviously ion thruster system requires manageable orientation of the satellite during in orbit.

So such a combined deorbit device based on 3U CubeSat will allow to test an opportunity of cleaning of near-Earth space by space debris.