Effective asteroid deflection through impulsive influence by the use of a high-thrust plasma-propulsion driven platform

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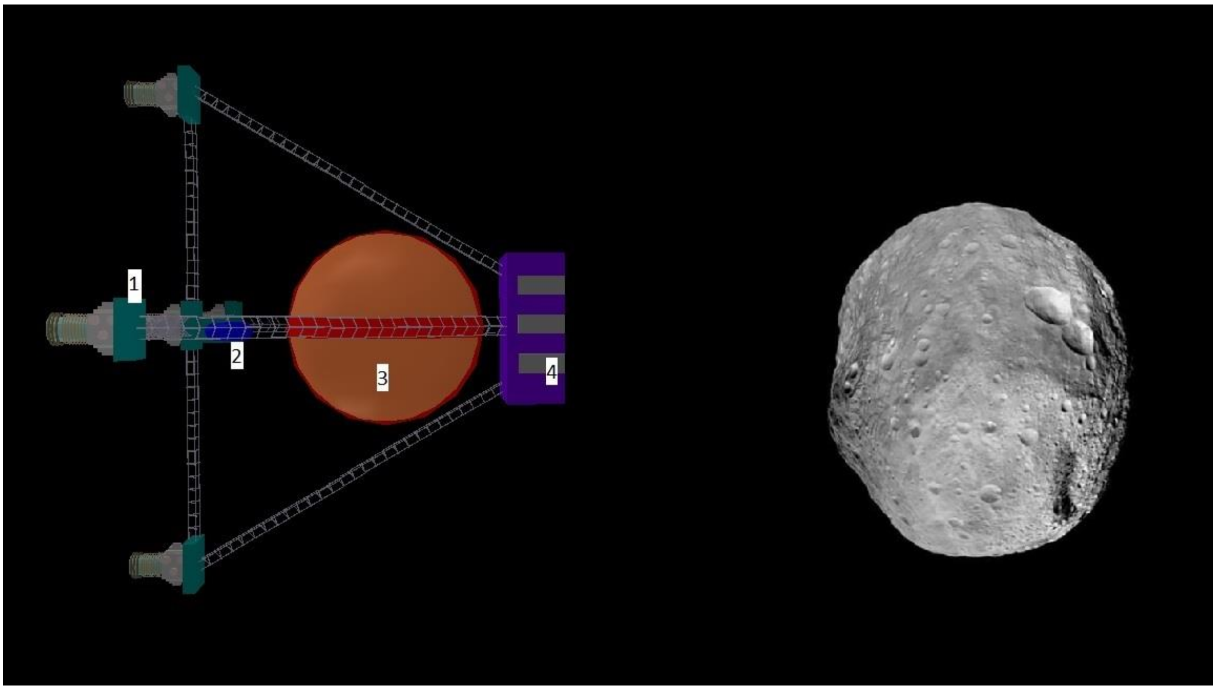
Abstract: One of the most significant threats from outer space is a massive celestial object with a path crossing the earth's solar orbit. It is obvious; from a statistic point of view such an event will be rather unlikely. But it can happen, and the consequences would be dramatic. A threat is always scaled by probability and effect. And in sum it is worth to be prepared, when the probability may be low but the potential expected effect is an extensive destruction of human habitat.

In general, there are two different opportunities to impact an asteroid and its orbit. One way is to try to destroy the whole asteroid by conventional or even nuclear explosives. But this procedure involves the risk that the number and sizes of the resulting pieces of the asteroid and their trajectories are almost not calculable. Therefore, it is unpredictable if one is decreasing the risk of an earth impact or even increasing it. The other way is to deflect the orbit of the asteroid and to prevent hereby a crossing with the solar orbit of the earth. Without assessing the chance of success, it seems clear that the approach of deflecting will at least not increase the threat compared with the one of destruction.



1 Setup of the spacecraft: 1-Propulsion unit, 2-Energy converter, 3-Fuel tank, 4-Deflection contact segment

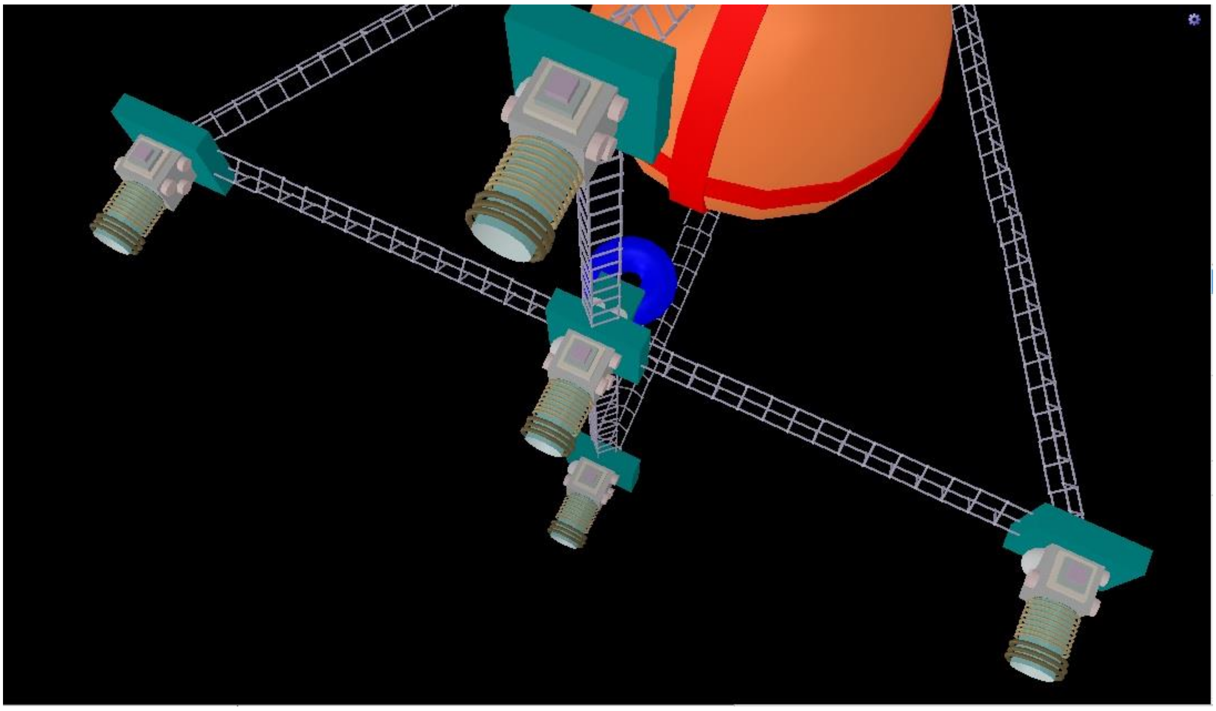
The concept of influencing and deflecting the trajectory of an asteroid as it is introduced within this paper consists of three different impulse transfer levels or mechanisms, respectively.

The first one is the impact impulse. The initial impulse, the space-craft is gaining on its journey to the asteroid, is the first choice regarding a possible deflection of the orbit of the asteroid. An impulse is basically defined as velocity of an object times its mass ($L = M\ x\ v$). The velocity is highly depending on the boundary conditions of the mission planning regarding calculation of the space-craft's orbit. It is doubtless that a maximum of velocity should be targeted; of course always within the limit of threatening the mission implementation. The second possibility to increase the impulse of the space-vehicle, and therewith the impulse transferred to the asteroid, is to raise the vehicle's mass.

A space-craft with comparable high mass may provide the benefit of a large impulse that is transferred to the asteroid, but there is at the same time the challenge to accelerate this craft in a reasonable time-frame. Hence, the equipment with a propulsion system that is able to generate higher thrust levels is crucial for the utilization of heavy crafts.

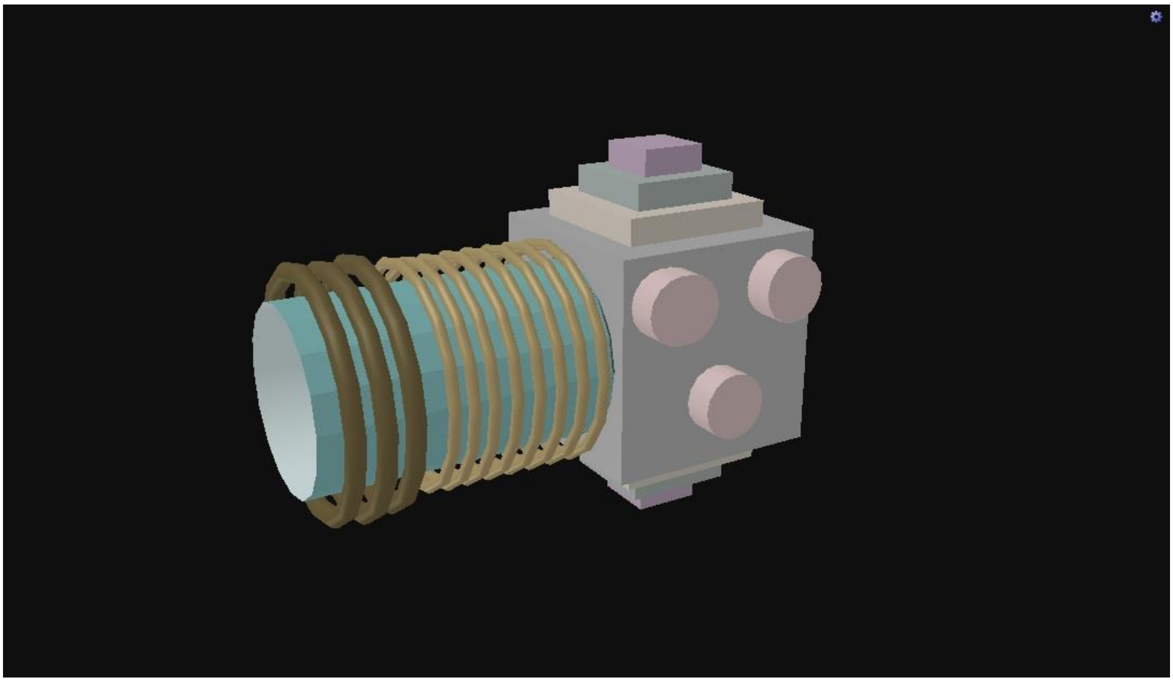
Impulse P_{impact} transferred to the asteroid during impact-phase:

$$P_{impact} = m_{vehicle}\ x\ v_{vehicle}$$



2 Thruster arrangement of the main propulsion unit

Most efficient for such a mission type would be a high-thrust plasma-propulsion system, like e.g. described with the "Helios"-thruster concept study. [1][2]



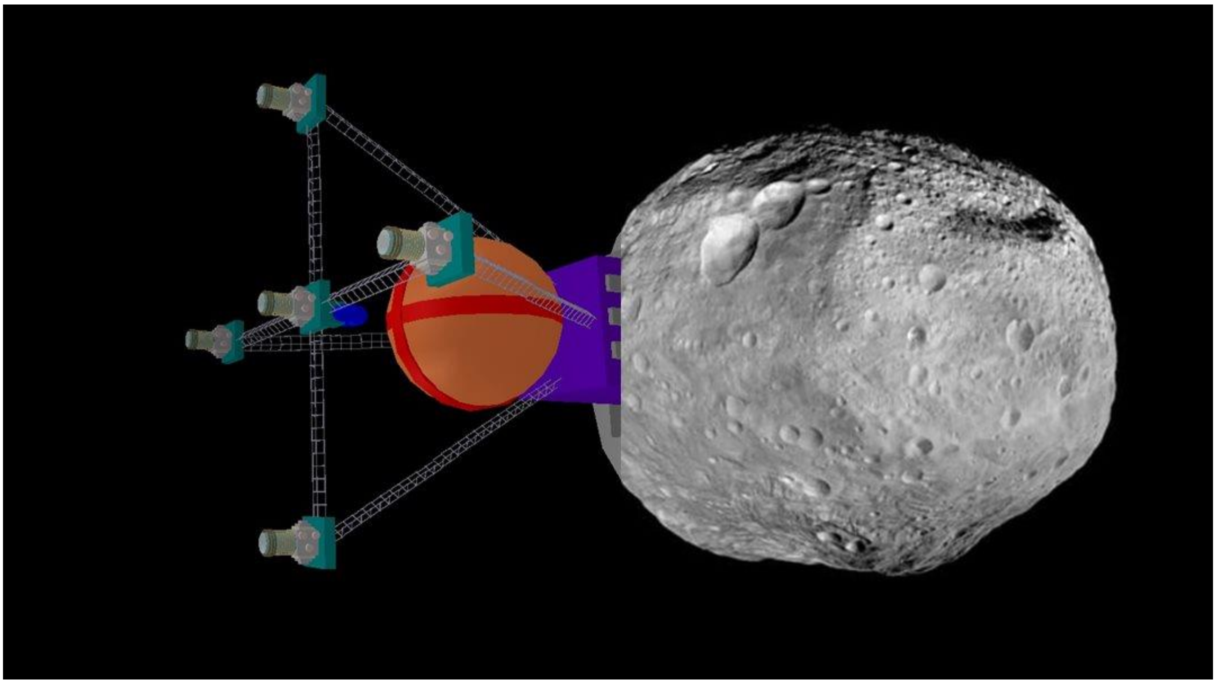
3 "Helios" thruster

The two major advantages of this kind of propulsion are obvious: First of all, and like with all kinds of electric space-propulsion (EP), the thrust performance is a continuous one. This fact enables a space-craft driven by EP to generate a thrust with a maximum of controllability; during the whole flight the course of the vehicle can be corrected. Especially for the reaction on sudden disturbances of the travel this feature is crucial. The even more important advantage of EP is the high velocity of ejected fuel-particles. This means that the limited and fixed amount of carried fuel is as efficient as possible converted into impulse onto the space-vehicle.

Above these general benefits of EP, the "Helios" plasma-thruster is designed to eject comparable large amounts of particles per time. In total, this thruster type adds a high thrust to the usual advantages of EP.

An additional benefit regarding an effective resource-sharing is the fact, that the propulsion module for this asteroid defence solution can one-to-one also be utilized as main thruster unit for an interplanetary exploration space-ship. [3]

The second mechanism is the transfer of thrust what again results in a transfer of impulse from the space-vehicle onto the asteroid during the firing period of the propulsion system after the vehicle is attached to the asteroid. For this type of mission a return of the space-craft is not scheduled. For this reason it is possible to use the whole remaining fuel after attachment to generate a direct thrust on the asteroid. Also for this task, a high thrust (transfer of impulse in short times) and high fuel exhaust velocity (high transferred impulse per fuel mass-unit) is a mission-benefit; what again recommends the use of high-thrust plasma-propulsion.

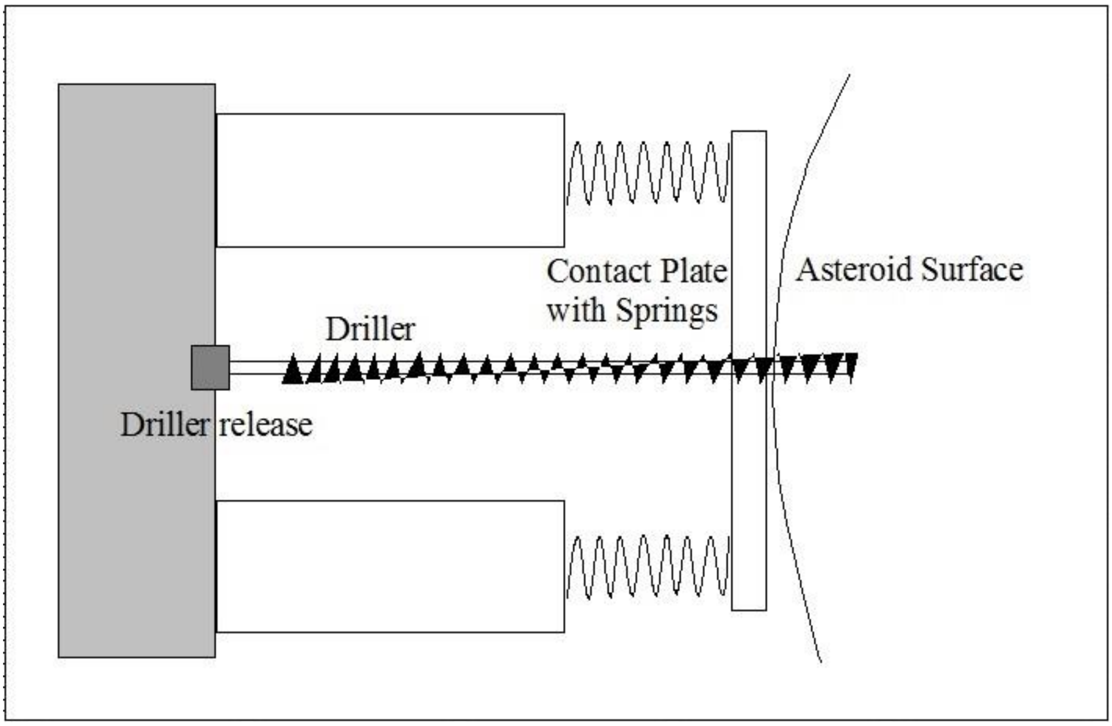


4 Direct thrust transfer from space-craft to asteroid

Impulse P_{thrust} produced by the firing thrusters during direct contact with the asteroid:

$$P_{thrust} \; = \; F_{thruster} \; x \; t_{firing} \; = \; \dot{m}_{fuel} \; x \; v_{fuel} \; x \; t_{firing}$$

And finally the third mechanism of transferring impulse is the release of the space-vehicle. According to the third law of Newton (actio=reactio), the repulsion of the space-craft pushing-back away from the asteroid is an impulse transferred onto the asteroid but in the opposite direction. But in order to generate repulsion during the release of the space-vehicle, it is necessary to establish a repellent force between vehicle and asteroid. For that purpose, the contact device is equipped with a driller. By drilling into the asteroid, the contact plate is pushed against the surface of the asteroid and springs behind the plate are compressed. The resulting tension of the spring produces a force which pushes vehicle and asteroid apart after releasing the driller.



5 Device for repulsive release

But due to the material the surface of the asteroid is made of, it may be excluded to conduct drill actions. The reason for this may be the hardness or the porosity of the surface. In such cases, an explosive charge at the contact plate is a possible alternative to generate repulsion between space-craft and vehicle.

The total impulse $P_{asteroid}$ which is transferred to the asteroid with the purpose to change its impulse and deflect its orbit therewith is the sum of the three single impulse transfer mechanisms:

$$P_{asteroid} = P_{impact} + P_{thrust} + P_{release}$$

References

[1] D. Kirmse: "Two concepts of high-thrust plasma-propulsion engines for use as main-thruster units for interplanetary exploration" 2014; http://vixra.org/abs/1408.0096

[2] D. Kirmse: "An estimation of power-consumption and thrust-generation at a medium-sized thruster of Helios-type" 2015; http://vixra.org/abs/1511.0161

[3] D. Kirmse: "A conceptual design of an interplanetary exploration spaceship with electric high-thrust plasma-propulsion of "Helios"-type" 2016; http://vixra.org/abs/1605.0297