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Title

Deflecting Asteroids using a Tractor Spacecraft with Opposing Rocket Engines

Abstract

It's only a matter of time before another asteroid big enough to cause a mass extinction event (like Apophis) wends its way toward Earth. This article proposes a tractor spacecraft which would rendezvous with the asteroid and, by use of opposing rocket engines, deflect it from its path.

Body of the Invention

It's only a matter of time before another asteroid big enough to cause a mass extinction event (like Apophis) wends its way toward Earth.

This proposal describes a tractor spacecraft with opposing rocket engines. The main engine at the back is used to guide the tractor spacecraft to a position orthogonal (at right angles) to the asteroid's path and pointing directly at the asteroid. Then the auxiliary "pusher" engine at the front, which is pointing toward the asteroid, is fired to oppose the effect of the main engine at the back. The pusher engine's thrust is continuously adjusted to balance the thrust of the main engine to keep the tractor spacecraft a fixed distance away from the asteroid. Both rocket engines are mounted on gimbals and can, along with smaller attitude thrusters, maintain position and orientation with respect to the asteroid (and Earth).

This same technique can also be used to herd space junk in near orbit to a predictable channel, or to "tugboat" passive cargo, for instance, redirecting an asteroid into a Lunar orbit for mining and research.

By directing the ejecta obliquely toward the asteroid, a variation of this technique can also be used to eliminate spin or tumbling of an asteroid to make it amenable to other techniques of deflection (or exploration).

The ejecta from the pusher rocket motor accelerates the spacecraft by basic Newtonian physics (Newton's Third Law of equal and opposite reaction). The rocket gases don't just disappear when they leave the spacecraft's engine. If the front engine is pointing directly at the asteroid (and close enough to its surface), that same ejecta will broadly strike the asteroid, imputing the same acceleration force on the asteroid in the opposite direction.

Since the ejecta is broadly striking the surface of the asteroid with the same direction/mass/velocity, it doesn't matter if the asteroid is spinning or if the asteroid is just a pile of rubble -- at the moment of impact for each ejecta particle, the net effect will be to impute a force in the correct direction to deflect the path of the asteroid.

An alternative solution where time is not a critical factor would be to use opposing attitude thrusters for the push effect and only use a single main rocket engine to transport the spacecraft into position. This may be more fuel-efficient and may allow finer control.

The ability to successfully deflect will be a function of:

1. Mass of asteroid
2. How far away it is when you intercept it and how fast it's going (specifically the amount of time you have before impact)
3. The mass of fuel you haul to the interception (divided by 2, remember there is a main engine and an opposing deflection engine)
4. The speed of ejection of your rocket motors (1/2 mass x velocity squared)
5. The number of interceptor/tractor spacecraft deployed (you can park as many as you want right next to each other)

The spacecraft would have an automated astral sextant and radar imaging sensors.

Given that astronavigation defines "North" as the direction toward Earth at this point in time (given Earth's orbit and whatnot), then one could define, using existing spacecraft guidance principles, a simple flowchart algorithm that combines a radar image of the target asteroid with an instruction like "use position thrusters and main engine and pusher engine to maintain a position of the spacecraft due-West x Inclination N relative to target and close enough so that target bounding ellipse occupies V% visual angle; keeping spacecraft pointing toward target". The "due-West" and "Inclination N" are the 3-D relative coordinate offsets determined by the launch crew to most efficiently deflect the asteroid. The V% visual angle can be calculated based on the distribution of ejecta from the particular pusher engine; one could imagine that it would be something like 90 degrees. (The intent being to allow a large majority of ejecta particles to strike the target -- since there is no friction in space to slow the particles, this could be set at a very high proportion, like 99%). Doppler radar could be used , if necessary, for finer control to maintain a fixed distance from the target object.

It is assumed that the most efficient main engine technologies will be adopted at deployment time, given the amount of time available for deflection. For instance, plasma rockets can accomplish more thrust with less fuel by virtue of the higher velocity in the ejecta according to basic physics. For example, the thrusting force is related to the consumption of fuel (mass) and the velocity in this equation: $T=dm/dt*v$). Other options might include ion engines (if you have a really long lead time) or nuclear powered rockets -- anything that accomplishes acceleration of a spacecraft by ejecting particles with some mass in the opposite direction.

When time is a critical factor, particle mass for the opposing engines could be harvested from icy asteroids or comets along the route to the asteroid.

Figure 1. System Context Diagram

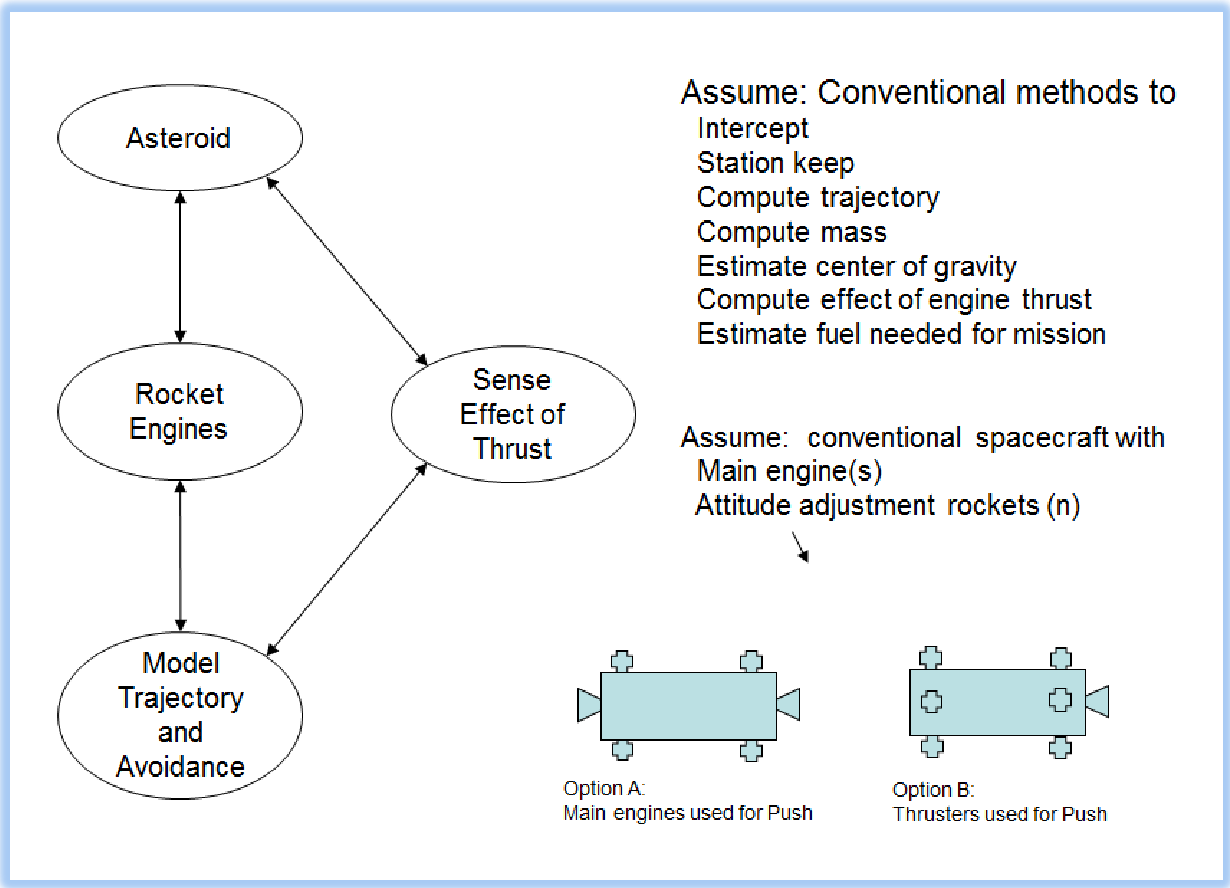


Figure 2. Guidance Flow Chart and Pictorial Representation

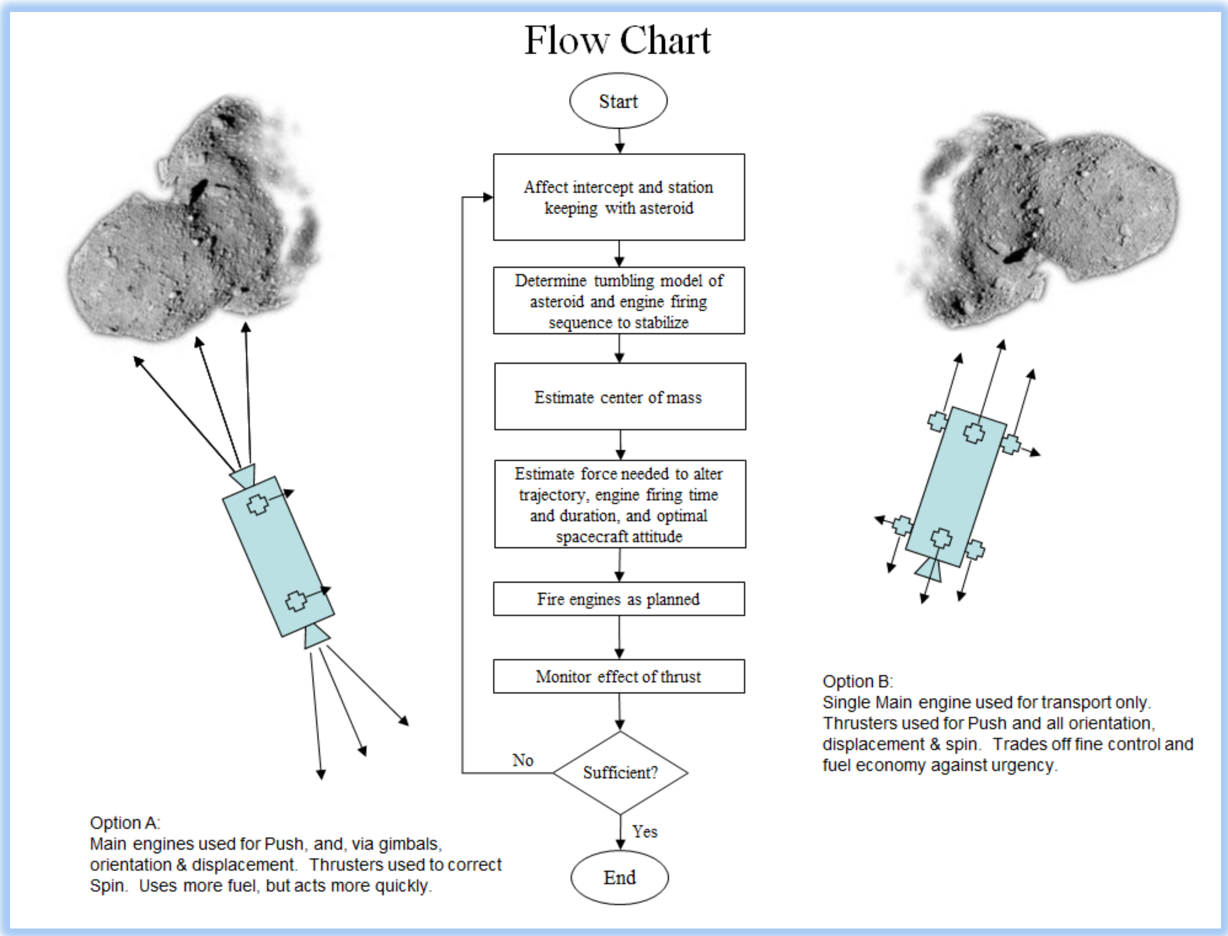
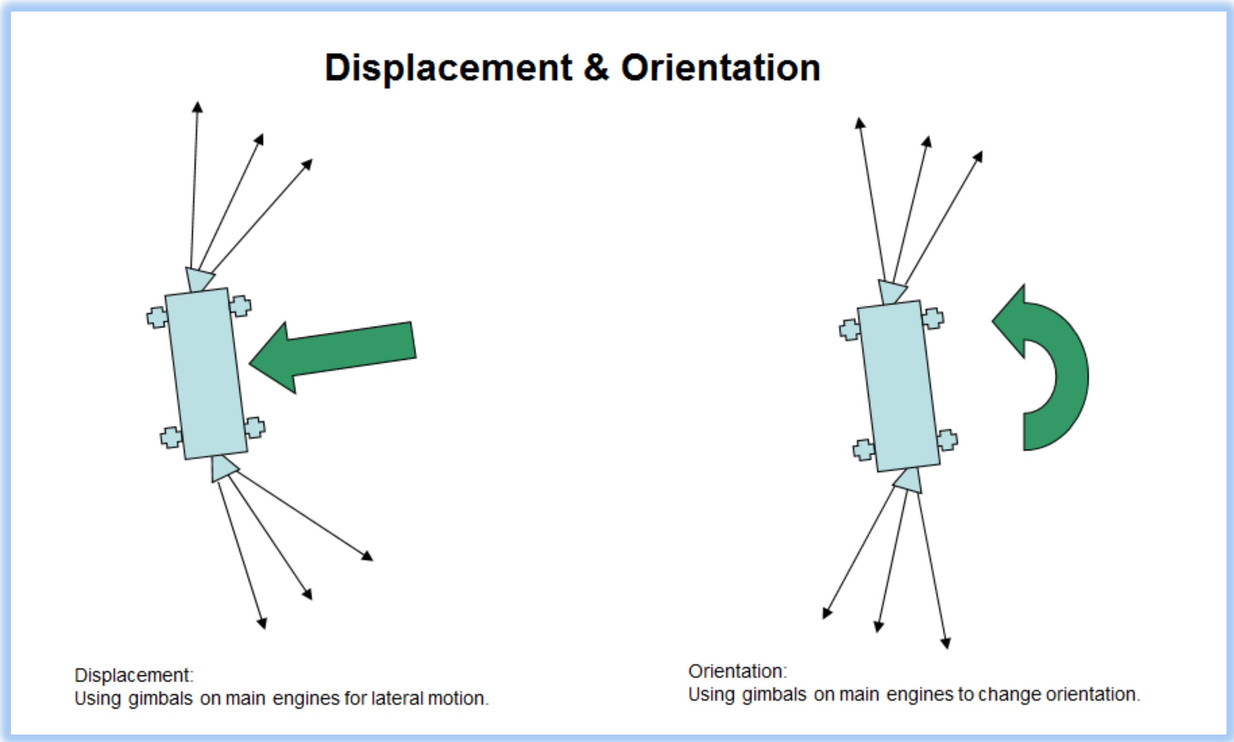


Figure 3. Adjusting Displacement & Orientation



Operability:

We anticipate that the spacecraft will use the same technology that the Space Shuttle (and Soyuz, etc.) have been using for decades to maintain fixed positions relative to the International Space Station -- and they do this with great precision, for instance, to affect docking maneuvers.

The fuel expenditure is balanced between the two engines to maintain a fixed distance from the asteroid. Various existing techniques (such as radar or laser range finding, accelerometers, gyroscopes, etc.) can be used to monitor attitude and distance relative to the asteroid and standard automated celestial navigation techniques can maintain the bigger picture relative to the asteroid's path toward the Earth.

References:

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