Chapter 19
Asteroid Capture

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19.1 Introduction

The scenario where a celestial body threatens to impact the Earth is very popular and many solutions have been proposed to mitigate the associated risk. Some of them can be considered “soft” and consist in landing on or rendez-vous with the incoming asteroid several years in advance of the collision and then altering its trajectory by various means, such as painting it in order to alter its albedo and therefore the radiation pressure or by pushing it gently using a gravitational tractor (Lu and Love 2005). The mechanical device described below could also be used to change the trajectory. All these scenarios need a lot of time, even discounting mission preparation. If the incoming body is not a near-earth object but, for instance, a comet nucleus, more than ten years are likely to be necessary to reach it. Some “hard” solutions do not require a rendez-vous, but an interception, possibly with a large relative velocity. They can be implemented on a much shorter time-frame. Detonating a nuclear device could disperse the incoming body as the gravitational binding energy of an asteroid is surprisingly low. The difficulty might then be the timing: the explosion should take place before the impact but late enough to create a strong absorption of its energy (mainly X rays), which would turn a percentage of the mass of the asteroid into hot gases generating a shock wave that could disperse the asteroid and additionally creating a mean impulse which would alter the trajectory of the centre of gravity of the cloud of debris. In (Massonnet and Meyssignac 2006), a two step procedure is proposed where a smaller asteroid is first captured and “parked” on a L1-L2 Earth-Sun Lagrange orbit, and then sent into a trajectory impacting the incoming threat.

19.2 The Concept

The concept involves detecting an easy-to-access asteroid, sufficiently light to allow altering its trajectory in three phases: first to capture it into an Earth-bound orbit, second to monitor and correct this orbit as a parking place, third to leave this orbit for a trajectory impacting any oncoming, threatening celestial body. For this last part the piloting law remains to be studied in detail. The main challenge is the low level of acceleration that can be applied by the propulsion mean proposed in (Massonnet and Meyssignac 2006), which should nevertheless always exceed any
trajectory instability that may develop. This use of a captured asteroid is the simplest one as the tools used for capturing the asteroid are the same as for handling it further. For using the asteroid as a source of extraterrestrial material such as oxygen only the two first steps are required, but they must be followed by an entirely independent extraction process. If it appears that adequate small size asteroids are currently transitioning between Earth-Sun Lagrange points, the first step may be omitted. The capture can be regarded as a “life insurance” and be undertaken without any actual threat, which would result in cutting considerably our reaction time should a threat materialize quickly. In (Massonnet and Meyssignac 2006), a good candidate for capture (SG344) as well as a time frame for the capture mission (2027-2029), were identified.

19.3 How to Push the Asteroid?

Here we review which options are available to create the few tens of meters per second we allocate for changing the trajectory on a “reasonable” time frame. By reasonable, we mean similar to the time required to cruise form the initial position to the parking position. This could last a couple of years but certainly less than ten years, even if the operation is conducted before any threat is materialized.

We first discard solar sails or other devices based on the change of the albedo of the asteroid. These methods might only find an application for altering an earthbound trajectory over many years, if we consider an asteroid with a diameter of 10 m and with the density of liquid water, a favourable case of 10000 kg per square meter of cross section, submitted to 1500 W/m², also a favourable case as it is the power radiated by the Sun at the level of earth orbit, then the acceleration will never exceed a typical 10⁻⁹ m/s². The asteroid gains 0.3 m/s every 10 years, changing its semi-major axis by some 10⁻⁵ in relative terms, and in turn its period by about the same order of magnitude. The asteroid would then typically be offset by a few minutes a year on its trajectory, where a typical 200 second offset may suffice to make an earthbound asteroid on a highly elliptical orbit miss its target. However, a capture may require tens of m/s rather that a fraction of one m/s.

Any other method of pushing the asteroid relies on the well known rocket equation which states that the logarithm of the mass ratio (the final mass plus the propellant mass divided be the final mass) equals the velocity ratio (the final velocity of the dry mass divided by the ejection velocity of the propellant). In short $V_F = V_E \ln\left(\frac{M_0}{M_F}\right)$ where $V_F$ is the final velocity, $V_E$ is the ejection velocity, $M_0$ is the initial mass (propellant mass and final mass) and $M_F$ the final mass. In the case of rockets the final mass is the sum of the structural mass and of the payload mass. If the rocket consists of several stages, the rocket equation applies to each stage.