



## Apophis Deflection With a Flotilla of Solar Shields

Jean-Yves Prado (1), Olivier Boisard (2)

(1) CNES, 2 Place Maurice Quentin, Paris ([jean-yves.prado@cnes.fr](mailto:jean-yves.prado@cnes.fr))

(2) U3P, 53 rue Amélie Vincendeau, 37530 Nazelles-Négron, France (<http://www.u3p.net>)

### Abstract

The possibility to use a solar sail for acting upon the orbit of a man-made object is well known.

What is presented in this paper is the capacity to use a solar sail like vehicle to change the orbit of a small body of the solar system by hovering over its sunlit surface.

One of the forces that affect the orbit of small bodies is a tiny but permanent thrust of thermal origin, the intensity and direction of which are directly related to the nature of the soil, the characteristics of the rotation and the physical properties of the body.

This effect is known as the Yarkovsky Effect. It concerns mainly hundred meter class asteroids. For smaller ones, the heat from the surface facing the Sun can travel through the inner core and the thermal variation on the surface is low. For larger ones, the effect is negligible due to their mass.

There are hundred thousands of small bodies of this type. About 10% of them are classified as Near Earth Object and one of them, Apophis, is of special interest.

Apophis has been discovered in 2004. Its diameter is estimated to be 270 meters. Its rotation period is around 30 hours so the Yarkovsky Effect on its orbit should not be negligible. These parameters and possibly others should be refined in 2012 when it can be observed again.

Apophis will make a very close (40,000km) approach to the Earth in April 2029. Depending on the geometry of its swing-by, it can be placed on an impact orbit to the Earth and present a danger for the

future decades. The areas that correspond to such trajectories are called Key Holes and are only a few hundred meter wide.

From the observations in 2012, it will be possible to determine the magnitude of the Yarkovsky Effect on Apophis and to greatly improve the prevision of its 2029 swing-by.

If the Yarkovsky Effect is found to be important, canceling it will be enough to avoid any key hole and prevent any future collision with the Earth.

This can be achieved by shadowing and cooling down the asteroid with a flotilla of solar shields. This new type of solar sails will have to counter the photonic pressure in order to maintain their hovering position.

In this paper, using observations made on 6489 Golevka, we show that the Yarkovsky Effect can alter the orbit of Apophis by up to several hundred kilometres within a decade and we propose a preliminary mission design and the main system requirements, especially as regards station keeping. Finally we discuss the pros and cons of this strategy and compare its effectiveness to already existing mitigation methods.