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A KINETIC-IMPACTOR DEMONSTRATION MISSION TO CHANGE THE SPIN OF AN ASTEROID

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Introduction

The NEOShield consortium consists of 13 institutes, universities and industrial partners from 6 countries. NEOShield addresses the global issue of preventing a hazardous NEO impact on Earth. The project is funded by the European Commission's Seventh Framework programme.

A major aim of NEOShield is to design technically and financially realistic deflection demonstration missions. Here we present a low-budget kinetic impactor demonstration mission concept.

The mission would determine the efficiency of momentum transfer during an impact, and help mature the technology required for a kinetic impactor mission, both of which are important precursor measures for a future space mission to deflect an asteroid by collisional means in an emergency impact hazard situation. Furthermore, the data gained from the mission would be of great benefit for our understanding of the collisional evolution of asteroids and the physics behind crater and ejecta-cloud development.

Mission Concept

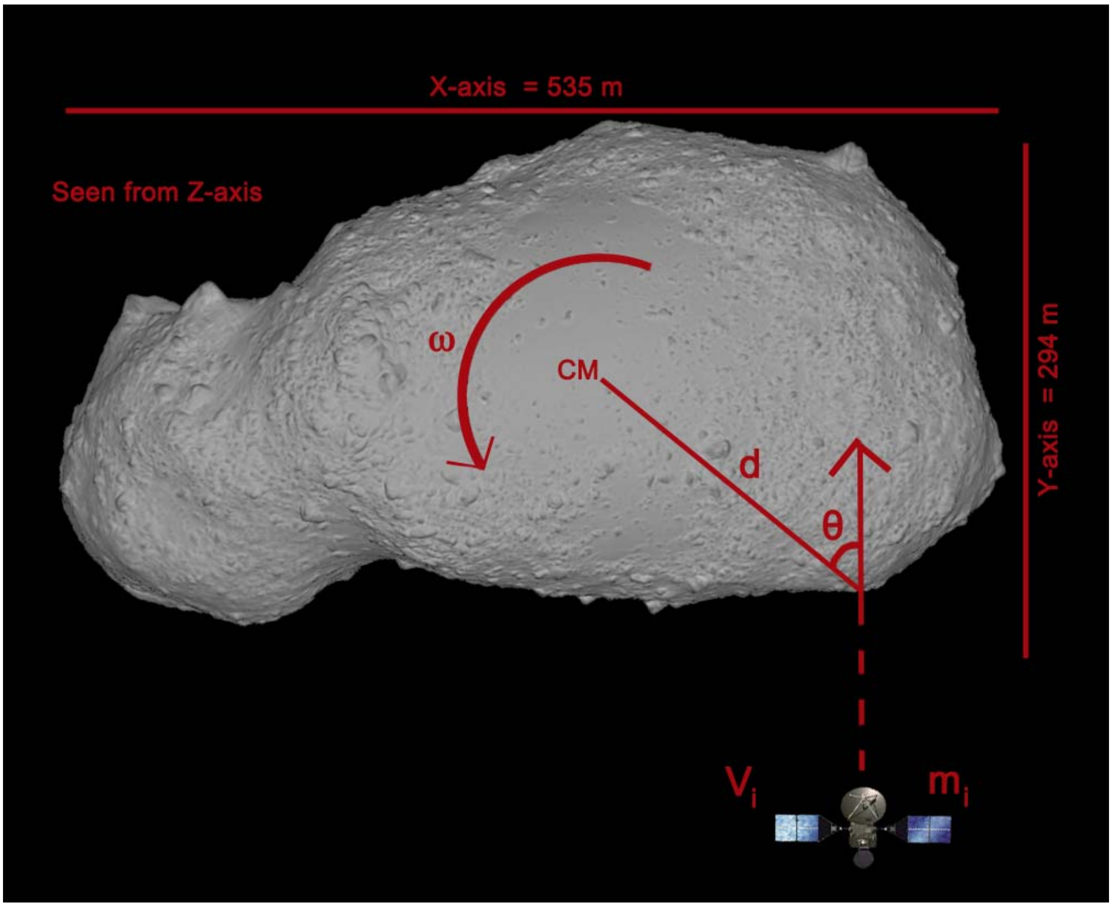

Figure 1. Illustration of a kinetic impactor changing the rotation period of an asteroid. Credit: Robert Gaskell produced the shape-model of Itokawa used.

Our concept is to measure the efficiency of the momentum transfer by impacting an asteroid far away from the rotation axis and thereby transferring angular momentum to it. This will cause the asteroid's rotational period to change, which can be observed from Earth by measuring the lightcurve. A reconnaissance spacecraft is therefore not essential.

This mission concept is not meant as a competitor to existing 2-spacecraft mission concepts, but as a low-budget alternative that could still provide valuable insight into the response of an asteroid to a kinetic impactor.

While not essential, the lack of a reconnaissance spacecraft to characterize the asteroid and observe the impact will reduce the scientific return. However using a previously visited asteroid as a target would partially compensate for this since some scientific context for the mission would already be available. Possible targets in this case could include (25143) Itokawa (Hayabusa I target, 2005), (101955) Bennu (Osiris-Rex target, 2018) and 1999 JU3 (Hayabusa II target, 2018).

As Itokawa is the only one of these to have been visited at the present time, it will be used as the example in the following (Fig. 1). In fact, Itokawa's elongated shape is advantageous for such a mission, as it facilitates impact far from the rotation axis and accurate measurement of its rotational period from lightcurves. The order of magnitude of a possible change in the spin period of Itokawa with such a mission can be estimated using the law of conservation of angular momentum (assuming no ejecta, an impactor of 500kg, an impact speed of 10 km/s and impact 200 meters from the rotational axis) results in a spin-period change of about 6.5 minutes (1% of the rotational period).

Spacecraft design

The mission can be designed as a single spacecraft impactor mission with a program of groundbased observations providing information on the physical effects of the impact. However, to observe the impact itself and the ejecta in detail, an observer spacecraft would be needed. To avoid a second launch, the mission can be planned to be similar to the Deep Impact mission, which was a two-part spacecraft that separated 24 hours before impact into an impactor and a flyby imager. The flyby imager slowed down slightly to observe the impact and then looked back to observe the ejecta cloud.

It is also possible to add cubesats to the mission, these would be ejected at a later stage from the impactor, and would give close up views of the impact and help to create a 3D image of the ejecta cloud.

Trajectory and observations

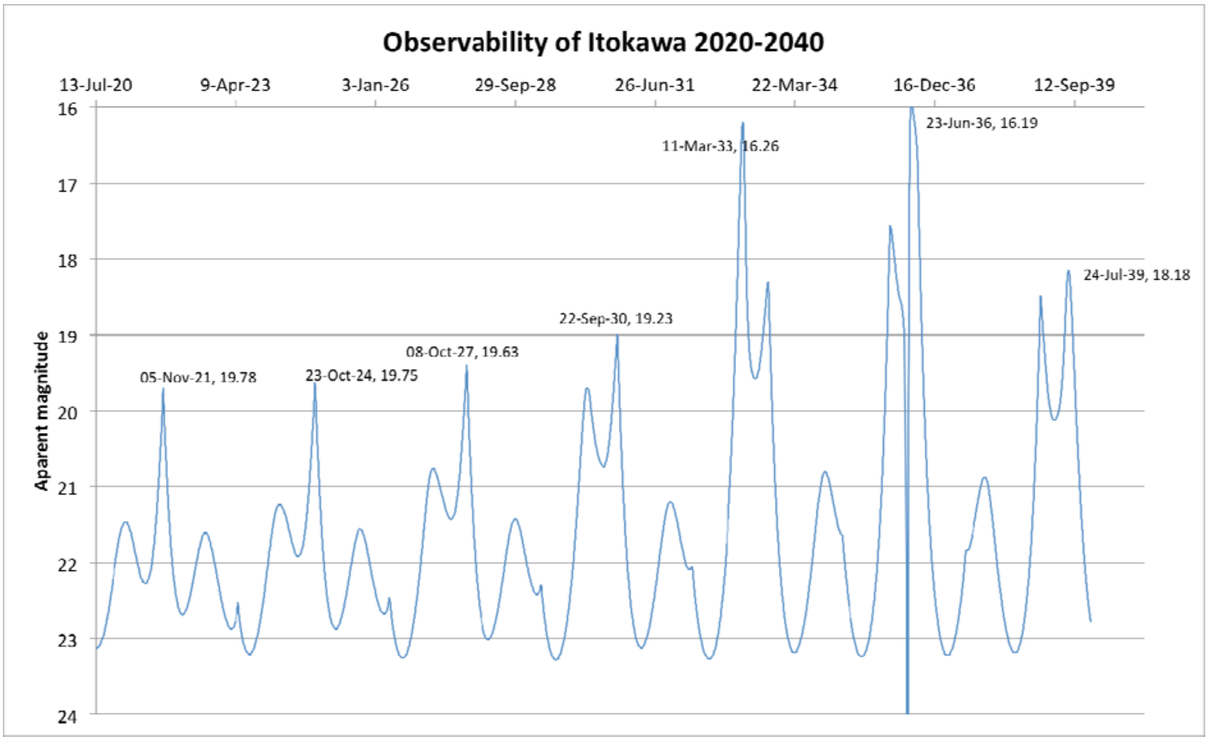

Figure 2. The apparent visual magnitude of Itokawa in the period of 2020-2040. Dataset from JPL Horizon

Figure 2 shows the apparent visibility in the 2020-2040 timeframe. Assuming the lightcurve will be observed with a 2-meter telescope, it should be possible to measure the rotation period of Itokawa in 2024 or 2027 to a precision better than half a minute. Using larger telescopes or waiting until 2033 it should be possible to measure the period with a precision of only a couple of seconds.

The minimum angular impulse moment that needs to be transferred for the uncertainty in measurement not to go over 10%, would mean that the change in rotational period should be more than half a minute. Assuming impacting at 200 meters from the rotational axis this would require $\beta m_i v_i \sin\theta$ > 370 kNs. As can be seen in Figure 3, this is easily achievable given the possible mission trajectories.

The actual change in spin rate achieved would provide a measure of beta, the ejecta-dependent momentum enhancement factor of crucial importance for any kinetic impactor mission.

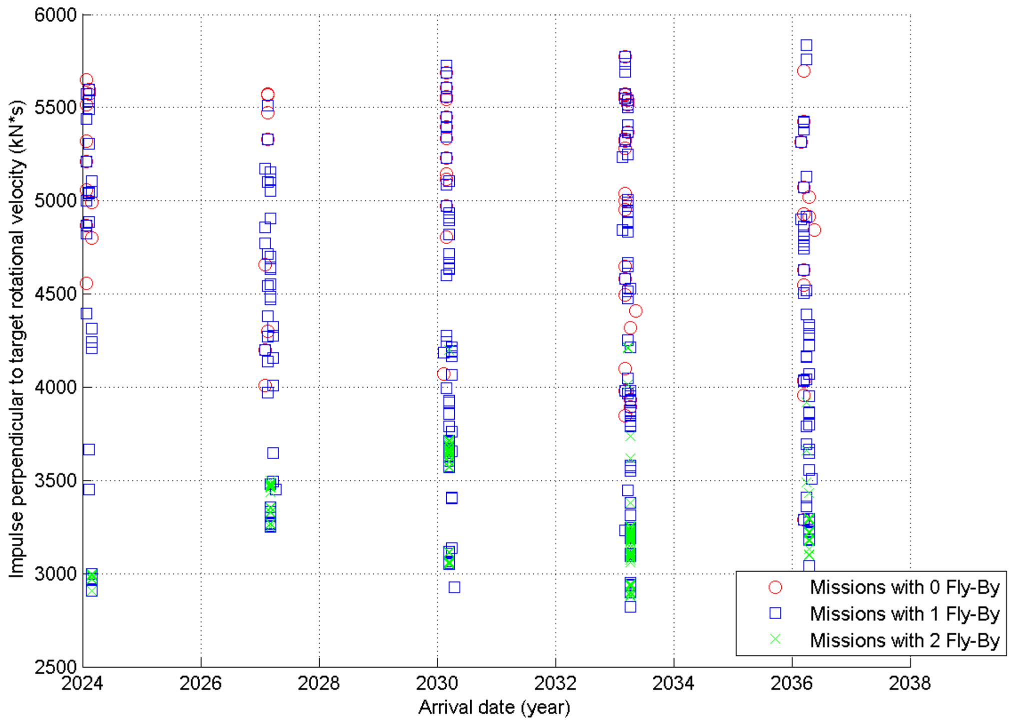

Figure 3: Impulse perpendicular Itokawa's rotation axis as provided by preliminary trajectory calculation assuming a Vega launch, where the upper stage is part of the impact mass. This is for a mission with no flyby imager. Credit: DEIMOS Space

YORP considerations

The YORP effect on the rotational period of Itokawa was measured from lightcurve data between 2001-2013 to be only ~0.45 ms / year [Lowry et al, 2014, Astron. Astrophys., 562, A48 (9pp)], which is about 5 order of magnitudes less than the changes from the impact discussed here, and is taken to be negligible.

Since the YORP effect is very shape-dependent, it may be instructive to re-measure and re-model the YORP-induced drift in the rotation rate after the impact.

Conclusion

Preliminary studies show that a mission concept in which an impactor produces a change in the spin rate of an asteroid could provide valuable information for the assessment of the viability of the kinetic-impactor asteroid deflection concept.

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