

Light Touch²

Effective Solutions to Asteroid Manipulation

Executive Summary

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Figure 1. AdAM mission logo

Motivation

The Light Touch² concept proposes the use of laser ablation to change the orbital velocity of a 4m, 130 ton, asteroid by 1m/s in less than 3 years. A laser beam is used to sublimate part of the asteroid material and generate a low and continuous thrust. This study demonstrates how to implement this concept on a medium class interplanetary spacecraft, here called AdAM (Asteroid Ablation Mission).

Methodology

The study presented an analysis of laser ablation for asteroid deflection proposing a simple one-dimensional model of the ablation process and the generation of the thrust. From this model, an analysis of the achievable momentum coupling C_m is presented. The momentum coupling is defined as the ratio between the achievable thrust and the power input to the laser. A second analysis showed the mass efficiency defined as the required mass of the deflection system (laser and associated power and thermal system) to produce a given thrust. The definition of the laser system included the optical system to focus and control the beam.

Starting from the definition of the laser and optical system, some requirements were derived on the navigation and control of the spacecraft in the proximity of the asteroid and on the size and characteristics of all the other subsystems on board the spacecraft. The small size of the asteroid and the fact that its ephemerides are not known with great accuracy required the definition of an advanced navigation strategy to detect, approach and rendezvous with the asteroid while simultaneously improving the knowledge of its ephemerides. Advanced GNC techniques were devised to control the spacecraft in the proximity of the asteroid during ablation and to measure the achieved deflection and modification of the rotational state of the asteroid.

The design of the spacecraft followed Astrium's principles of system engineering, maximising the reliability and robustness, demonstrating that the mission is feasible with current technology.

Results

- Based on the current model and experimental results, laser ablation is comparable, in terms of C_m , to an electric propulsion contactless deflection system, and can surpass an electric propulsion system in terms of mass efficiency in the case of high Δv .
- The target 1m/s of variation of velocity can be achieved in less than one year of push time even with a relatively small laser.
- The laser system can be installed on a medium sized spacecraft employing high TRL technology. No special developments are required except for the laser system itself. The dry mass of the spacecraft, considering a dedicated fully chemical propulsion system to complete the transfer, can be as low as 453kg. Further mass reduction is possible by optimising some components and relaxing some conservative assumptions.
- The GNC strategy devised in this study can identify and rendezvous with the asteroid and improve its ephemerides during approach. The GNC strategy can also accurately reconstruct both the orbital and rotational motion of the asteroid prior to the beginning of the ablation and during the ablation. A high level of autonomy is gradually achieved, assuring safety at low operational costs.

Publications

- One abstract was submitted to the Planetary Defence Conference 2013.

Highlights

Two results are particularly interesting and deserve further investigations.

- The laser ablation concept was shown to achieve momentum couplings comparable to electric propulsion deflection systems with a better mass efficiency. This result is based on the current 1-dimensional model and the outcome of some experimental results. Further investigations are required to perfect the model and make the prediction of the performance reliable for all expected classes of asteroids. More experimental work is required in this sense, along with an improvement of the efficiency of lasers for high power outputs. The additional interesting aspect of laser ablation is the extraction and analysis of surface and subsurface material. Laser ablation is therefore an interesting candidate for asteroid exploitation but also for new science missions that would significantly improve our knowledge of the composition of asteroids.

- The techniques developed in this study to identify and improve the ephemerides of the asteroid in space and to accurately estimate its orbital and rotational state are very interesting, and warrant further development. They represent an enabling technology that would allow for the improvement of our knowledge of the motion of asteroids.