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Light-Touch^2: A Laser-Based Solution for the Deflection, Manipulation and Exploitation of Small Asteroids

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ABSTRACT

This paper presents the preliminary mission and system analysis of a small-scale, light-weight system for the deflection, manipulation and exploitation of small size asteroids. The system proposed in this paper, called Light-Touch^2, uses lasers to ablate the surface of an asteroid and induce a low thrust modification of its orbit. The system is applied to the deflection of a small size asteroid, 2-4 m in diameter.

Ablation is achieved by irradiating a small portion of the asteroid with an intense laser light. The material under the spot light absorbs part of the incident light and increases its the temperature to the sublimation point. At this point the material transforms directly from a solid to a gas. The ablated material then expands to form a plume of ejecta. This exerts a small thrust which pushes the asteroid away from its initial trajectory.

In this paper it will be demonstrated that a laser system powered by conventional solar arrays can produce enough thrust to change the velocity of a small 130 tons asteroid by 1 m/s in less than 3 years. The concept has been already demonstrated analytically and experimentally within the laboratory environment[1]. Although this paper presents the results for a very small size asteroid, the concept was demonstrated to be scalable and applicable to larger asteroids up to 200-300m in diameter[2].

The use of laser ablation represents also a unique opportunity to extract surface and subsurface material that can be analysed in situ through simple spectroscopy or returned to Earth. In fact, laser ablation results in the subsurface tunnelling and volumetric removal of material. This drilling mechanism releases deep and previously inaccessible material that is

chemically identical to the source material. This material could not otherwise be retrieved through conventional in-situ and sample return based missions. The plume of ablated ejecta could be examined remotely though in-situ analysis (i.e. emission spectrum and mass spectroscopy) or collected and/or return to Earth for further analysis. A spacecraft could fly through portions of the plume, gathering material by an aerogel collection plate or other externally mounted collection devises. The collected material could then be used as part of a sample return mission and/or for a resource exploration and exploitation based mission. Asteroids could also be captured within an Earth bound orbit and laser ablation could be used to mine the asteroid to collect resources. This would enable scientists and engineers to further characterise the composition, formation and evolution of asteroids and other small, rocky bodies.

The current mission and system design to implement the Light-Touch^2 concept envisage a small class satellite, called AdAM (Asteroid Ablation Mission), conceptually inspired by NASA's Stardust mission[3] (see Figure 1). AdAM will fly in formation with an asteroid, similar to 2008 JL24, and apply laser ablation for a suitability long time to significantly modify the orbit of the asteroid.

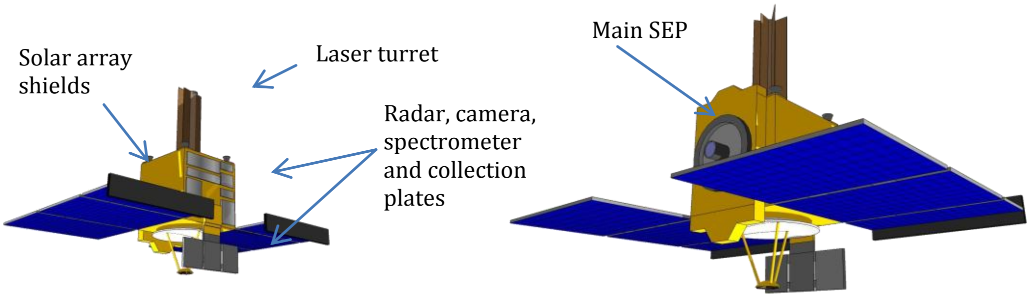

Figure 1. Current AdAM conceptual configuration

AdAM is equipped with a solar-pumped kW class, or smaller, fibre laser. Both continuous wave and pulsed solutions were considered. Pumping is provided directly from a set of standard solar arrays. AdAM will also be supported by a number of instruments for in-situ measurement and material collection. The latter includes spectrometers and a number of collection plates.

In the paper, the Light-Touch^2 concept is compared against other known contactless deflection systems. Assessed qualities include momentum coupling and mass efficiency. The system and mission analysis will also be complemented by navigation analysis. A combination of ground-based and onboard optical measurements will be used to provide the required accuracy to fly in formation with the asteroid and to measure the deflection. The paper will therefore present the preliminary spacecraft system analysis and the preliminary transfer and navigation analysis. This is combined with the current momentum coupling model. A technology road map will also be presented. This study was completed within the ESA SYSNova programme.

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