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EXPLORING AND DEFLECTING ASTEROIDS WITH LASER ABLATION

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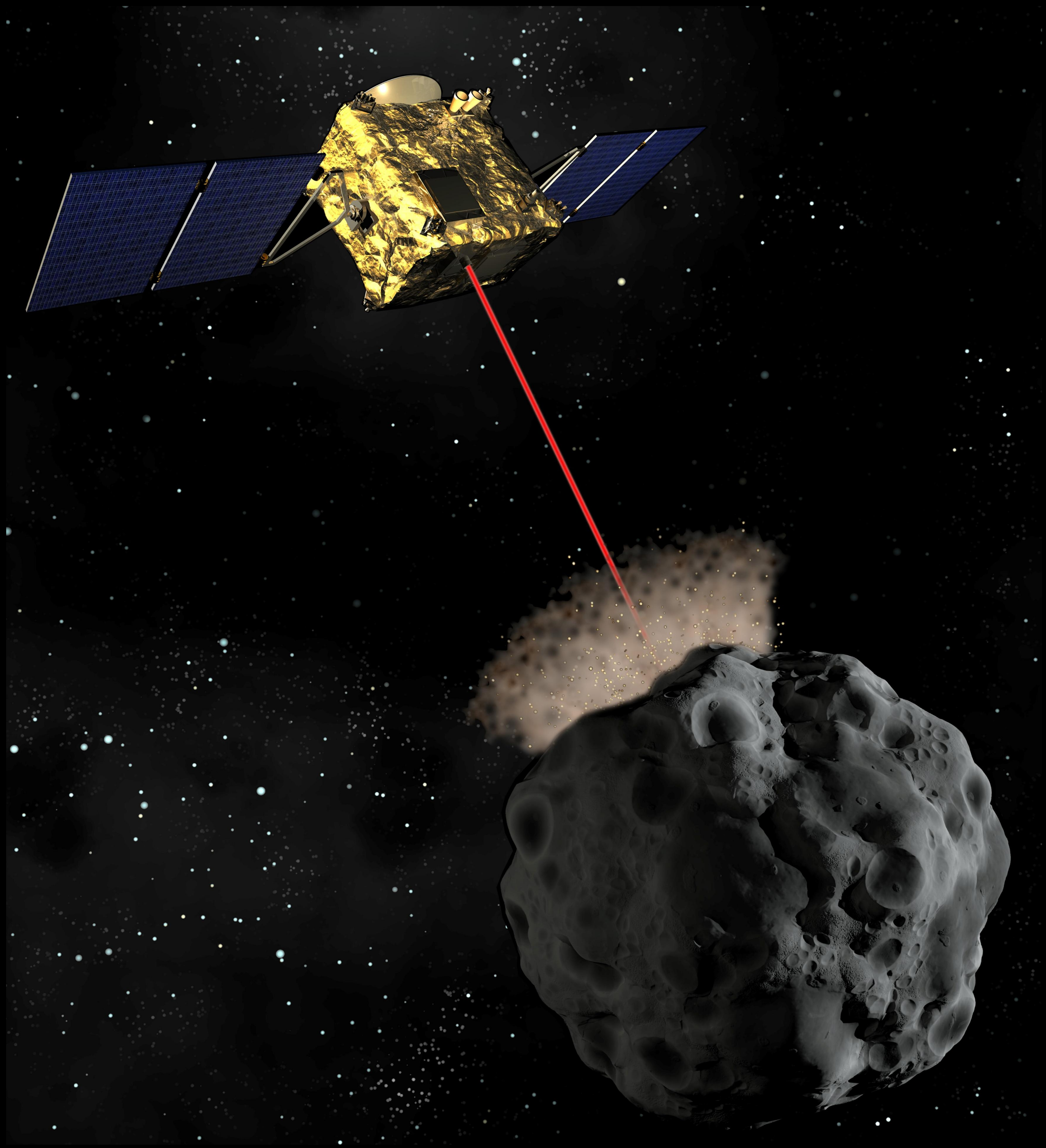


ASTEROIDS

Asteroids, the rocky remains from planetary accretion, represent both an opportunity and a risk. Their pristine environment captures the early impact evolution of the solar system, whereas their impact potential could result in the mass extinction of life. To address this combined theme, laser ablation has been investigated as a novel technique for the exploration and mitigation of asteroids.

Laser ablation is achieved by irradiating the surface of an asteroid with a laser light source. The resulting heat sublimates the surface material, transforming the exposed material directly from a solid to a gas.

The ablated material then expands to form into an small and extended plume of ejecta. Over an extended period of time, the ejecta plume acts against the asteroid. This provides a continuous, yet controllable low-thrust push that can be used for the deflection, manipulation and exploration of small and medium size asteroids.

The study demonstrated the capability of a relatively small, yet highly efficient space-based laser system. It also verified the laser's proof-of-concept, the spacecraft's preliminary mission design and the feasibility of its in-space application.

THE MISSION

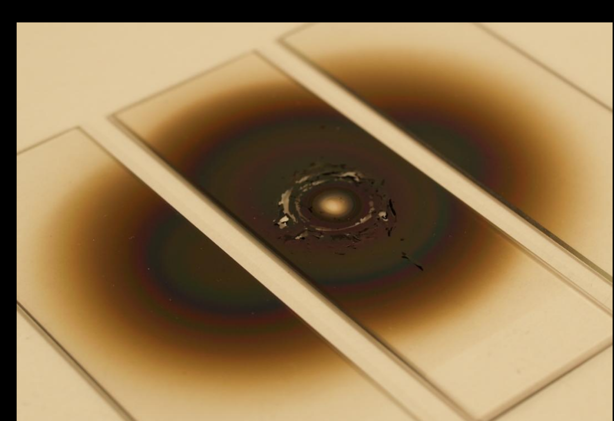
Launched in 2027, a small-scale spacecraft (960 kg) will be ejected into geostationary transfer orbit via a PSLV launch vehicle. An onboard bipropellant chemical propulsion system will be used to escape and rendezvous with the 4 m in diameter target asteroid (2006 RH120). Payload selection includes:

- A 860 W diode-pumped fibre-laser, operating with an overall efficiency of 55 %, 1070 nm wavelength and an asteroid-to-spacecraft distance of 50 m.
- An impact sensor will be used to measure momentum created by the ablated ejecta.
- A Raman Laser Induced Breakdown Spectrometer (LIBS) This will examine the chemical composition of the plume. It includes both volatile and refectory elements.

The LIBS is the secondary, opportunistic science payload. Assessment includes the spectral dispersion, geometry and response of the ejecta plume. This is combined further with the guidance, navigation and control cameras.

The 960 kg spacecraft is powered by deployable solar arrays and onboard batteries. Thermal control is achieved passively by body mounted radiators, heat pipes and multi-layering insulation. Reaction control thrusters, star trackers, sun sensors and an inertia reference unit are used for acquisition and orientation. A Laser range finder and two optical cameras provides navigation and control. Communication is achieved by a 1.3 m high gain antenna and a X-band link with the ESA Harwell 12 m ground station.

The mission requirement was to deflect the asteroid by at least 1 m/s, with a mission life of under three years. With a surface spot size of 0.8-1 mm this could be achieved with a push time between 165-220 days. The total thrusting time would be divided into several ablation phases, each lasting 30 days and followed by a dedicated orbit determination phase. This resulted in a momentum coupling coefficient of $1.5*10^{-5}$ N/W and a peak thrust of 10 mN. This exceeds the performance of a gravity tractor and ion beaming. Mission mass and system complexity is minimised by the direct ablation of the asteroid's surface.



OPPORTUNISTIC SCIENCE

Experiments have shown that laser ablation results in the subsurface tunnelling and volumetric removal of deeply situated and previously inaccessible material. This is due to the formation of a subsurface groove and the ejection of highly volatile material. The ejection of material is elementally identical to the original source material, although the absorptive properties are considerable different. It resulted in the deposition of a fine, powder-like material that can be easily removed.

Extracted raw material from asteroids can include: iron-nickel, magnesium, platinum, yttrium, titanium, hydrogen and oxygen. Laser ablation offers an unique, yet feasible and contact-less method for the deflection, extraction and analysis of material.

This can be used to expand and maximise the capabilities of any remote sensing, in-situ and/or sample return mission. This would enable scientists to further characterise the composition, formation and evolution of asteroids, and other rocky bodies throughout the solar system. Laser ablation provides a revolutionary diagnostic technique.

Additionally, laser ablation can be used for commercial exploitation and exploration. A self-sustaining space economy could be provided by the capture and harvest of asteroids within an Earth-bound orbit. Extracted material can be used for in-situ space construction, the formation of deep-space propellant deposits and provide continual life-support for future human exploration. This highlights the diversity of using space-based lasers.

Laser ablation offers a unique opportunity

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