EXPLORING AND EXPLOITING ASTEROIDS WITH LASER ABLATION

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ASTEROIDs
LASER ABLATION

Laser ablation is achieved by irradiating the surface by a laser light source. The resulting heat sublimes the surface, transforming it directly from a solid to a gas.

Following ablation, large jets of ejecta - gas, dust and large particles - are created. This forms an ejecta cloud & subsequent change of momentum.

Over an extended period of time, provides a continuously low thrust,
MISSION SCENARIO

Induced thrust, $F(t)$

Debris plume

Proximal Motion Orbit

Helocentric NEO orbit
The spacecraft(s) consist of:

- A primary mirror, $M_1$
  Focuses the solar rays onto the secondary mirror, $M_2$.
- A set of solar arrays, $S$
  Collects the radiation from the secondary mirror
- A semi conducting laser, $L$
- A steering mirror, $M_d$,
  Directs the laser light onto the asteroids
- A large set of radiators $R$,
  Dissipate energy to maintain the solar arrays and laser within the acceptable mission design limits.
MISSION SCENARIO

Ejecta depends on the available energy & efficiency of the ablation process

[ Vasile & Maddock, 2010; Phipps 2010; Sanchez, 2009; Kahle 2006 ]

Plume profile is similar to a rocket exhaust
Using standard methods of rocket propulsion
Uniformly expanded gas of ejecta
No solid particles
Expanded with a constant scatter factor – 180 degrees

Assumed a spherical, dense, homogenous body
Forsterite (Mg2Si04) is typically used
Asteroid has an infinite heat sink
Constant internal temperature during ablation

Ejected particles will immediately condense and stick
Assumptions on the degradation and attenuation
The rate of ejecta defines the modulus and direction of the total forces, and therefore the induced motion, exerted onto the asteroid.

Development of the ejecta significantly affects the contamination and operations (i.e. endurance) of any optical surface.

\[ \rho(r, \theta) = \rho \times A_p \frac{d_{\text{spot}}^2}{(2r + d_{\text{spot}}^2)^2} \left[ \cos \left( \frac{\pi \theta}{2\theta_{\text{MAX}}} \right) \right]^{2/k-1} \]

[Kahle et al, 2006]
MISSION SCENARIO

The rate of ablation can also be increased with:

- The number of spacecraft
- Combined laser coupling
- Warning/thrusting time

Multiple spacecraft permit the delivery of a much more powerful system.
System redundancy can also be increased.
EXPERIMENT

Performing a series of ablation experiments using a 90 W continuous-wave laser

Investigating the development of the ejecta plume, potential for contamination and induced change of momentum during laser ablation.

Calibrate and validate the development of numerical models and existing theory [Vasile & Maddock, 2010; Sanchez et al, 2009]
EXPERIMENT

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EXPERIMENT
OBSERVED TRENDS

Variation in cone angle, mass flow, and distribution

Ablation process includes solid ejecta particles

Subjected to the volumetric removal of material

Sensitive to the focal point of the laser

Local depositions in and around the ablation volume

$T_0 \sim 0.5 \text{ sec}$

Subjected to the structure and composition of the target material

$T \sim 1 \text{ min 14 sec}$

[Gibbings, Vasile et al 2011]
Laser ablation can be used for a wide range of space-based missions

**MISSION SCENARIO**

- In-situ Spectra Analysis
- Collection & Sample Return
- Resource Extraction
- Asteroid Deflection
- Capture & Control

**Durability and diversity of a space-based laser system**
Thank you for your attention. Questions please.
References


