University of Strathclyde
Advanced Space Concepts Laboratory
INSTITUTE OF PHOTONICS

EXPLORING AND EXPLOITING ASTEROIDS WITH LASER ABLATION

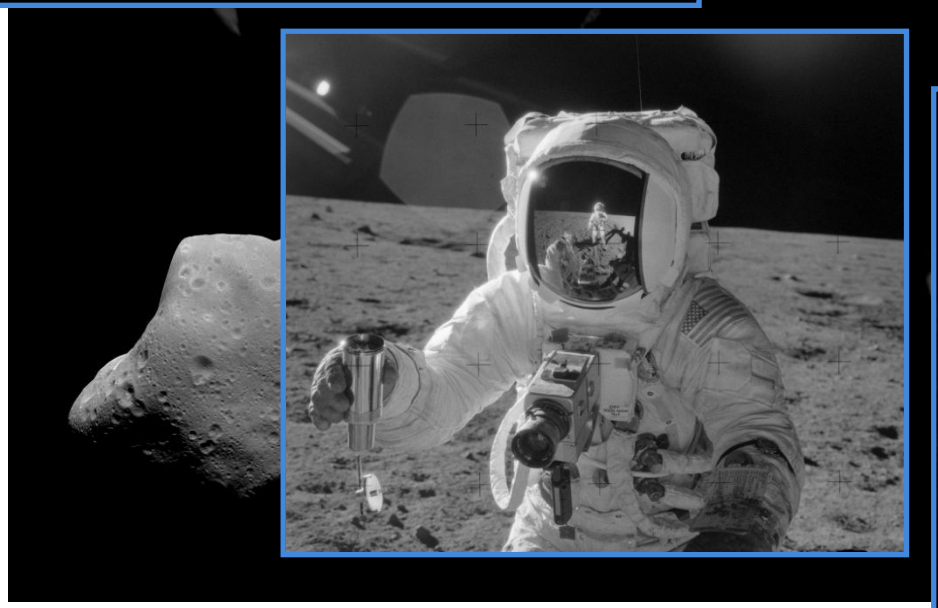
Alison Gibbings

Dr Massimiliano Vasile, Dr John-Mark Hopkins,
Dr David Burns, Dr Ian Watson

frontier research on visionary space systems

www.strath.ac.uk/space

ASTEROIDS

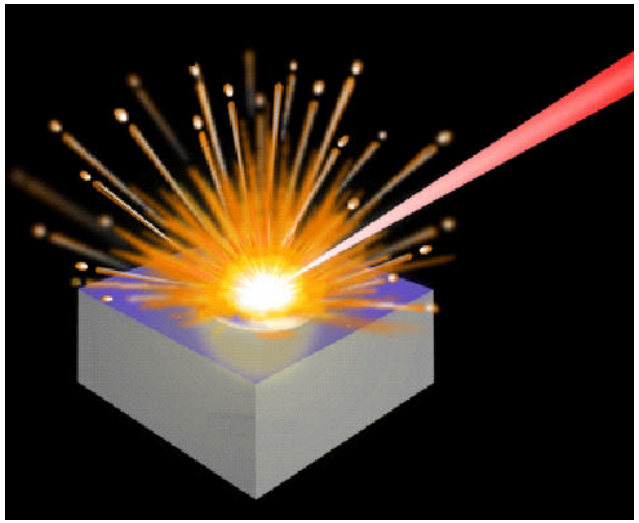
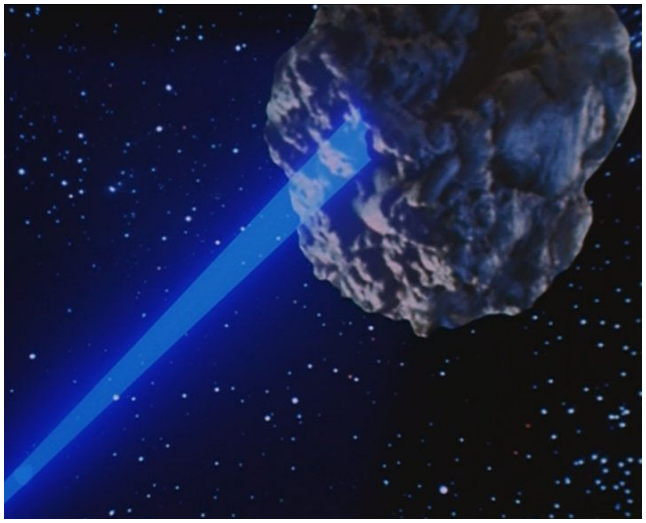


agibbing@eng.gla.ac.uk

LASER ABLATION

University of Strathclyde
Advanced Space Concepts Laboratory

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

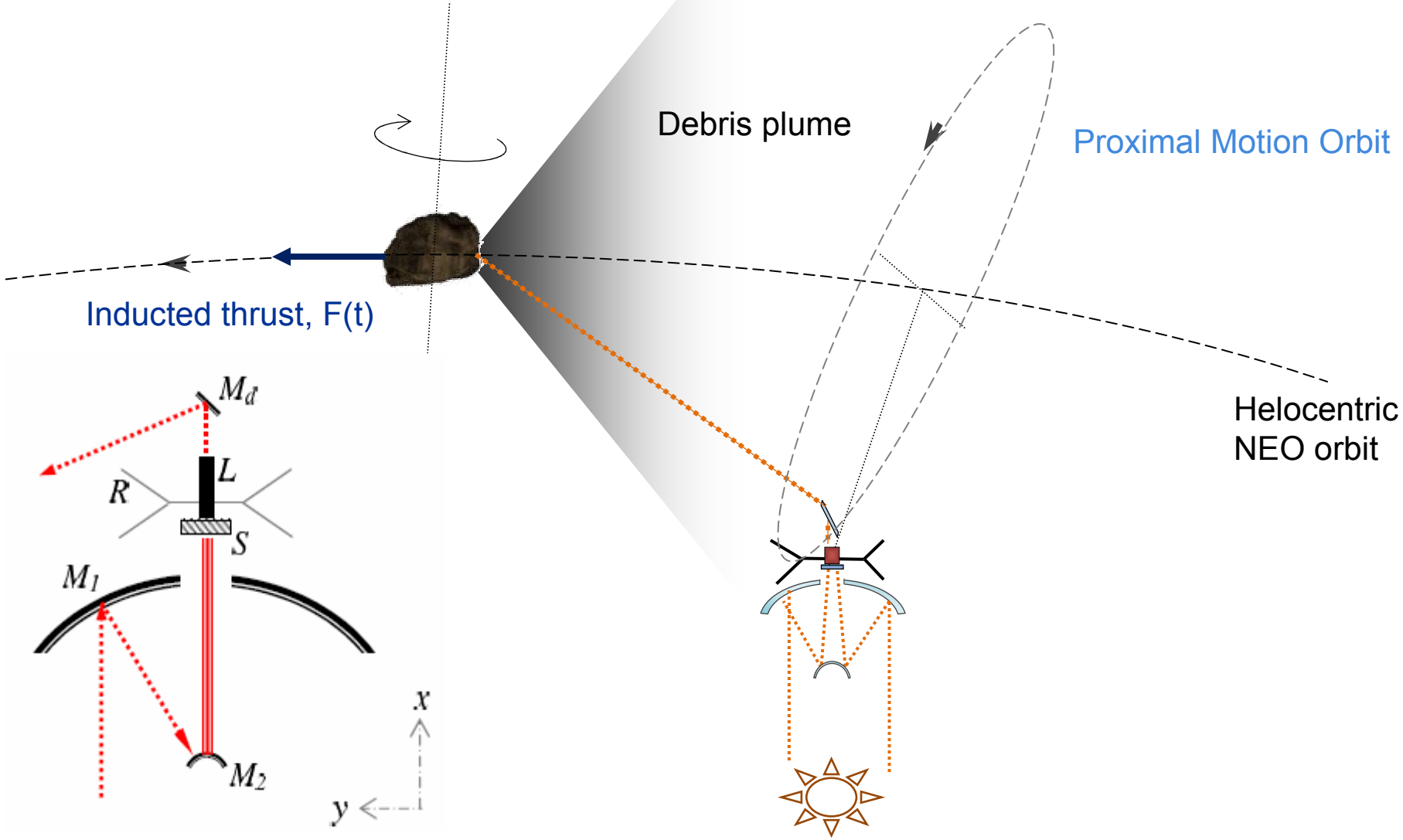




Following ablation, large jets of ejecta - gas, dust and large particles - are created. This forms an ejecta cloud & subsequent change of momentum.

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

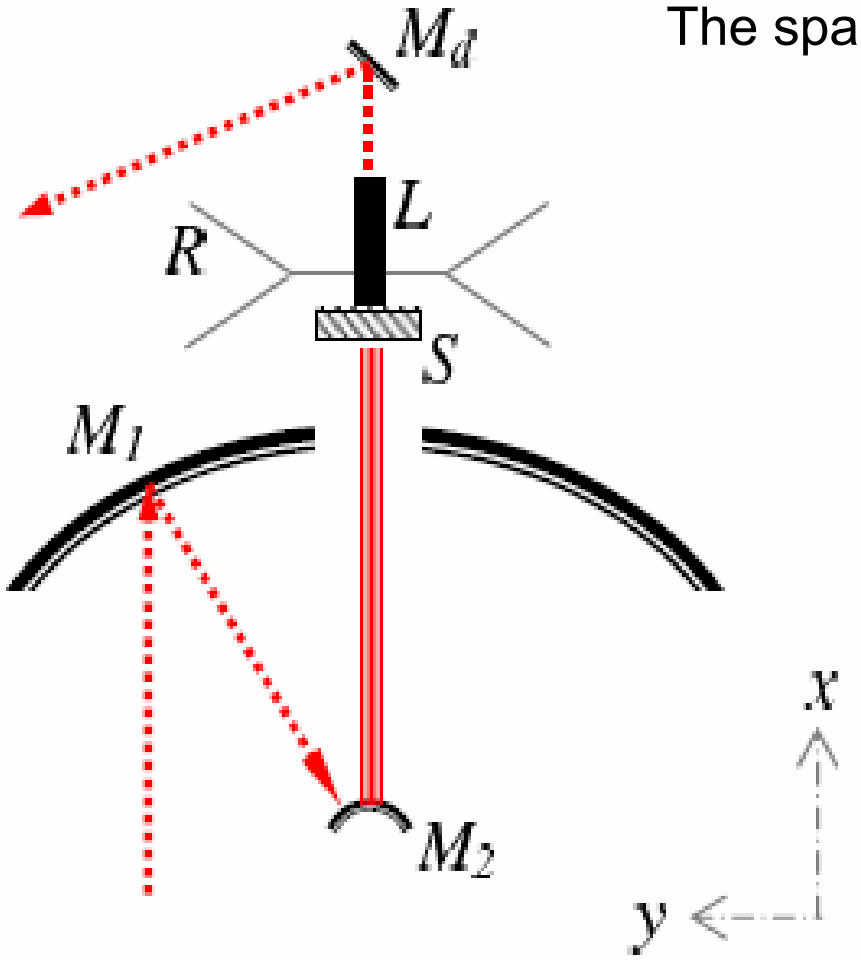
agibbing@eng.gla.ac.uk

MISSION SCENARIO



agibbing@eng.gla.ac.uk

MISSION SCENARIO



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.

agibbing@eng.gla.ac.uk

MISSION SCENARIO

University of Strathclyde
Advanced Space Concepts Laboratory

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

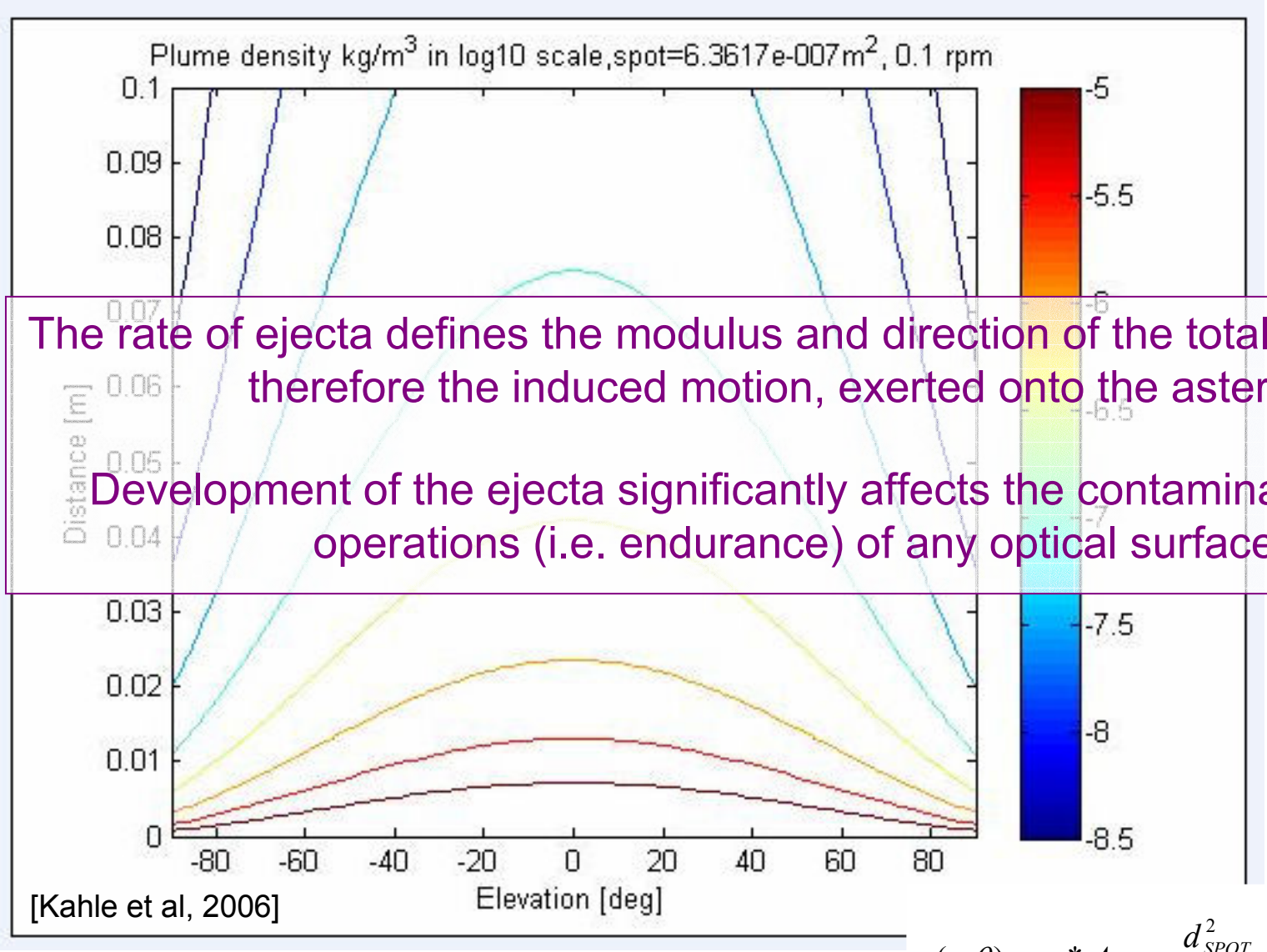
- Forsterite (Mg2Si04) is typically used
- Asteroid has an infinite heat sink
  - Constant internal temperature during ablation

Ejected particles will immediately condense and stick

- Assumptions on the degradation and attenuation

agibbing@eng.gla.ac.uk

MISSION SCENARIO



[Kahle et al, 2006]

The rate of ejecta defines the modulus and direction of the total forces, and therefore the induced motion, exerted onto the asteroid.

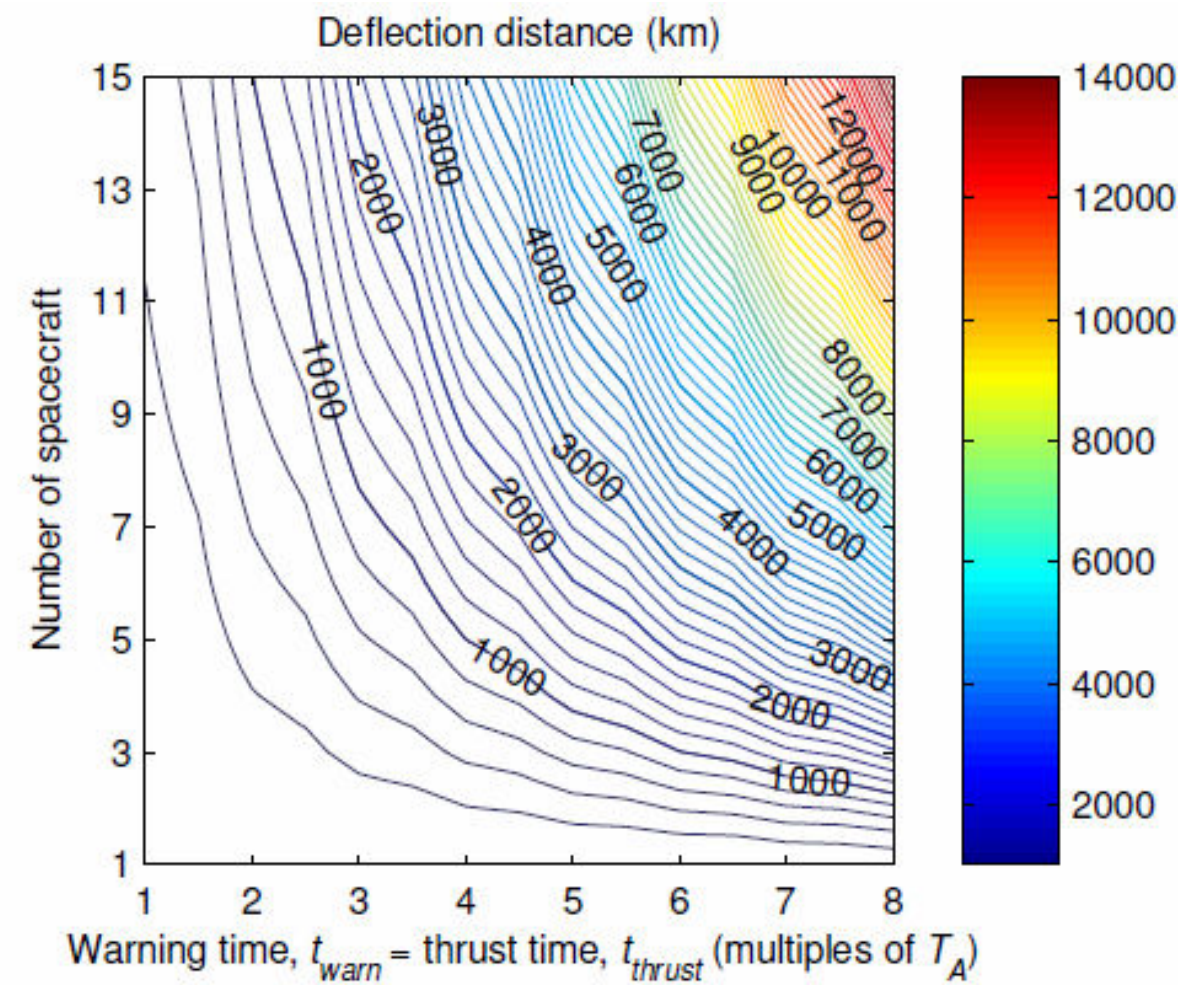
Development of the ejecta significantly affects the contamination and operations (i.e. endurance) of any optical surface

$$\rho(r,\theta) = \rho * A_P \frac{d_{SPOT}^2}{\left(2r + d_{SPOT}^2\right)^2}\left[\cos\left(\frac{\pi\theta}{2\theta_{MAX}}\right)\right]^{\frac{2}{k-1}}$$

agibbing@eng.gla.ac.uk

MISSION SCENARIO

The rate of ablation can also be increased with:

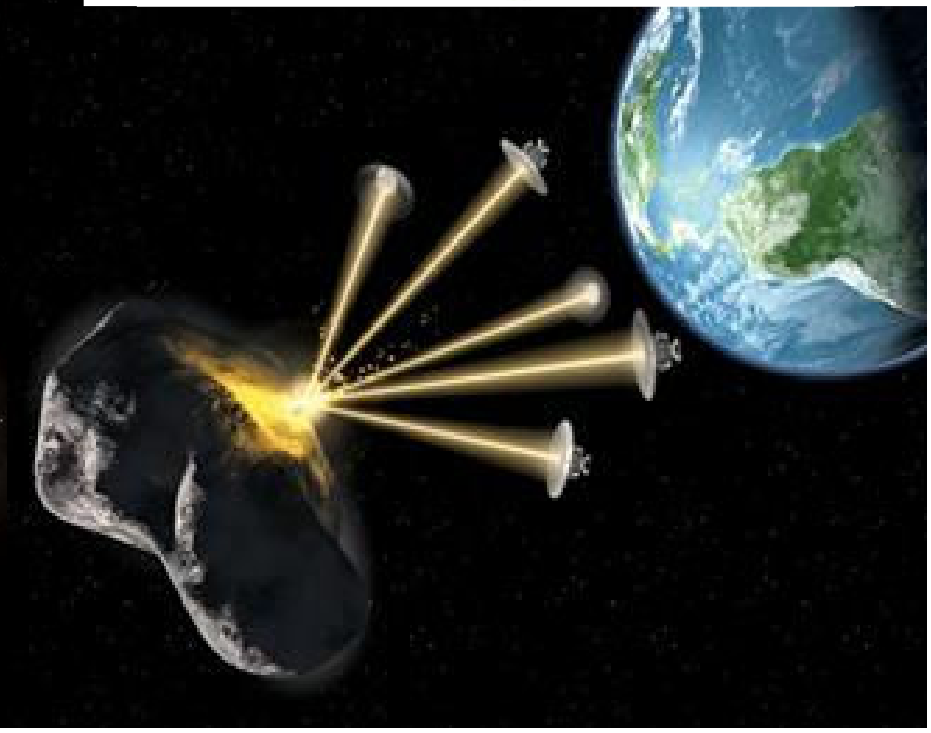


- The number of spacecraft
- Combined laser coupling
- Warning/thrusting time

Multiple spacecraft permit the delivery of a much more powerful system

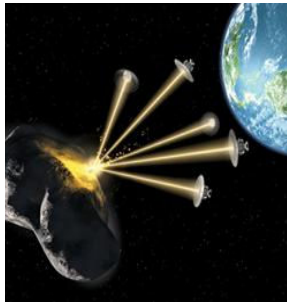
System redundancy can also be increased

agibbing@eng.gla.ac.uk



agibbing@eng.gla.ac.uk

EXPERIMENT



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

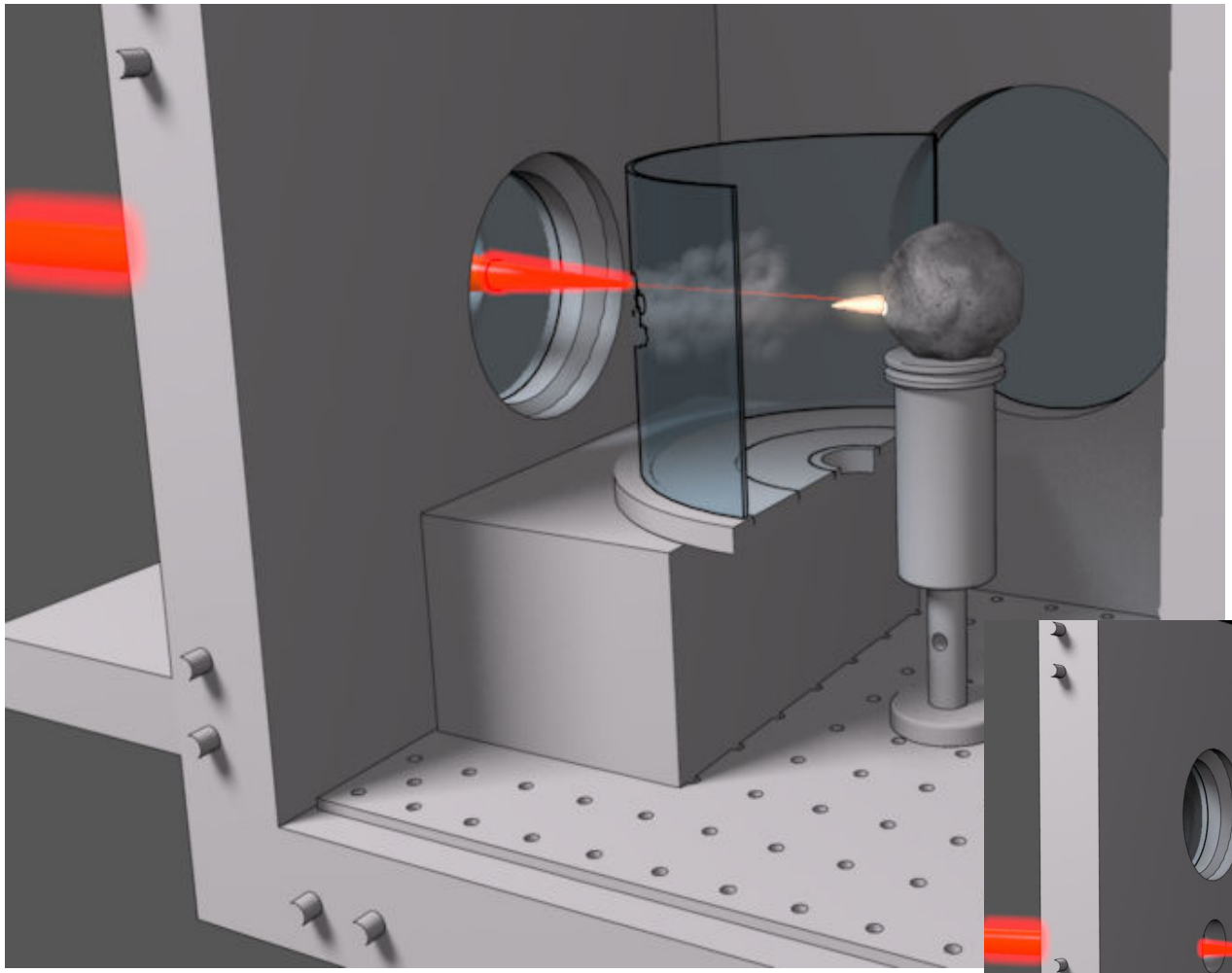
Investigating the development of the ejecta plume, potential for contamination and induced change of momentum during laser ablation.

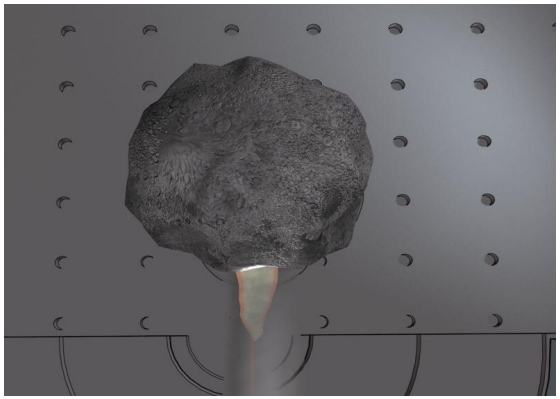
Calibrate and validate the development of numerical models and existing theory [Vasile & Maddock, 2010; Sanchez et al, 2009]

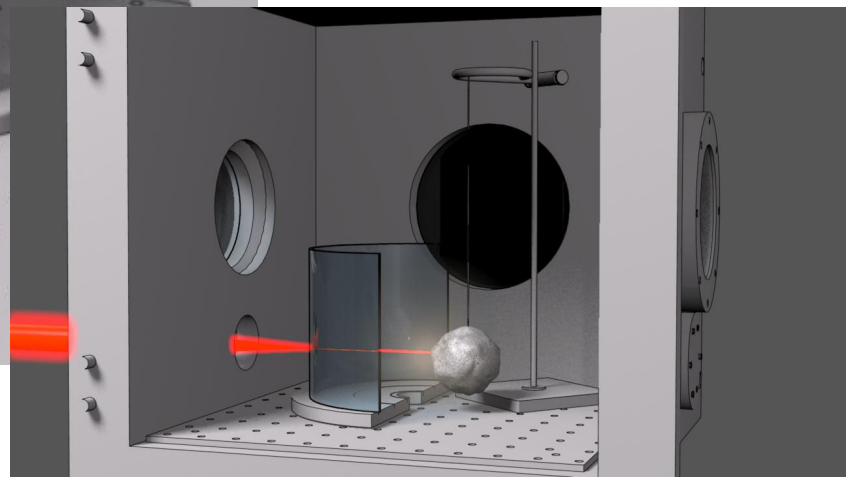
EXPERIMENT

University of Strathclyde
Advanced Space Concepts Laboratory

INSTITUTE OF PHOTONICS







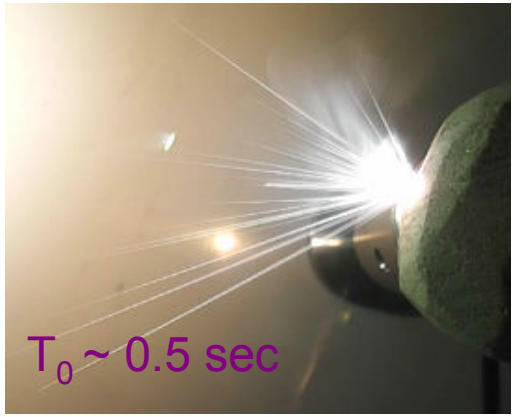
agibbing@eng.gla.ac.uk

EXPERIMENT

University of Strathclyde
Advanced Space Concepts Laboratory

agibbing@eng.gla.ac.uk

OBSERVED TRENDS



Subjected to the structure and composition of the target material

Variation in cone angle, mass flow, and distribution

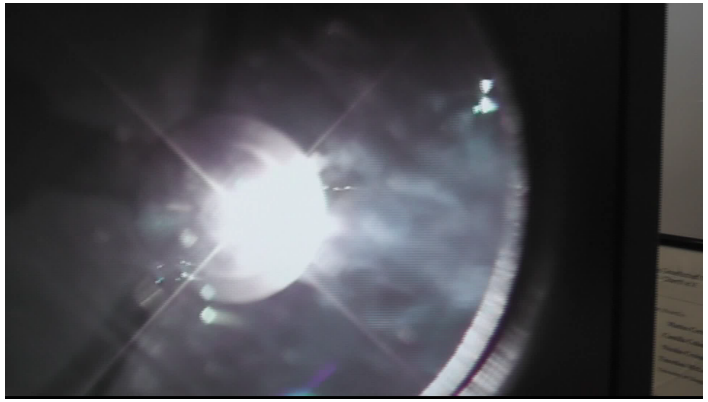
Ablation process includes solid ejecta particles

Subjected to the volumetric removal of material

Sensitive to the focal point of the laser

Local depositions in and around the ablation volume

[Gibbings, Vasile et al 2011]



agibbing@eng.gla.ac.uk

MISSION SCENARIO

University of Strathclyde
Advanced Space Concepts Laboratory

Laser ablation can be used for a wide range of space-based missions

In-situ Spectra Analysis

Collection & Sample Return

Resource Extraction

Asteroid Deflection

Capture & Control

Durability and diversity of a space-based laser system

University of Strathclyde
Advanced Space Concepts Laboratory

Thank you for your attention. Questions please.

agibbing@eng.gla.ac.uk

References

Gibbings A, Vasile M, Hopkins J-M, Burns D "On Testing Laser Ablation Processes for Asteroid Deflection" 2011 IAA Planetary Defence Conference, Bucharest, Romania, 9-12th May 2011

Kahle R, Kuhrt E, Hahn G, Knolenberg J "Physical Limits of Solar Collectors in Deflecting Earth-threatening Asteroids" Advanced Science and Technology, Vol 10, pg 256-263, 2006

Phipps C, Birkan M, Bohn W et al "Review: Laser Ablation Propulsion", Journal of Propulsion and Power, Vol 26, No 4, 2010

Sanchez, J.P., Colombo, C., Vasile, M., et al "Multicriteria comparison among several mitigation strategies for dangerous Near-Earth objects". *J. Guid. Control Dynam.* 32, 121–141, 2009.

Vasile M, Maddock C "On the Deflection of Asteroids with Mirrors", *Journal Celestial Mechanical Dynamics*, Vol 107, pg 265-284, 2010

Vasile M., Maddock C., Radice G., McInnes C "NEO Deflection though a Multi-Mirror System", ESA Call for Proposals: Encounter 2029, Final Report for Ariadna Study Contract 08/4301, Technical officer: Summerer L., March 2009.

agibbing@eng.gla.ac.uk