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LASER ABLATION FOR THE EFFECTIVE DEFLECTION, EXPLORATION AND EXPLOITATION OF ASTEROIDS

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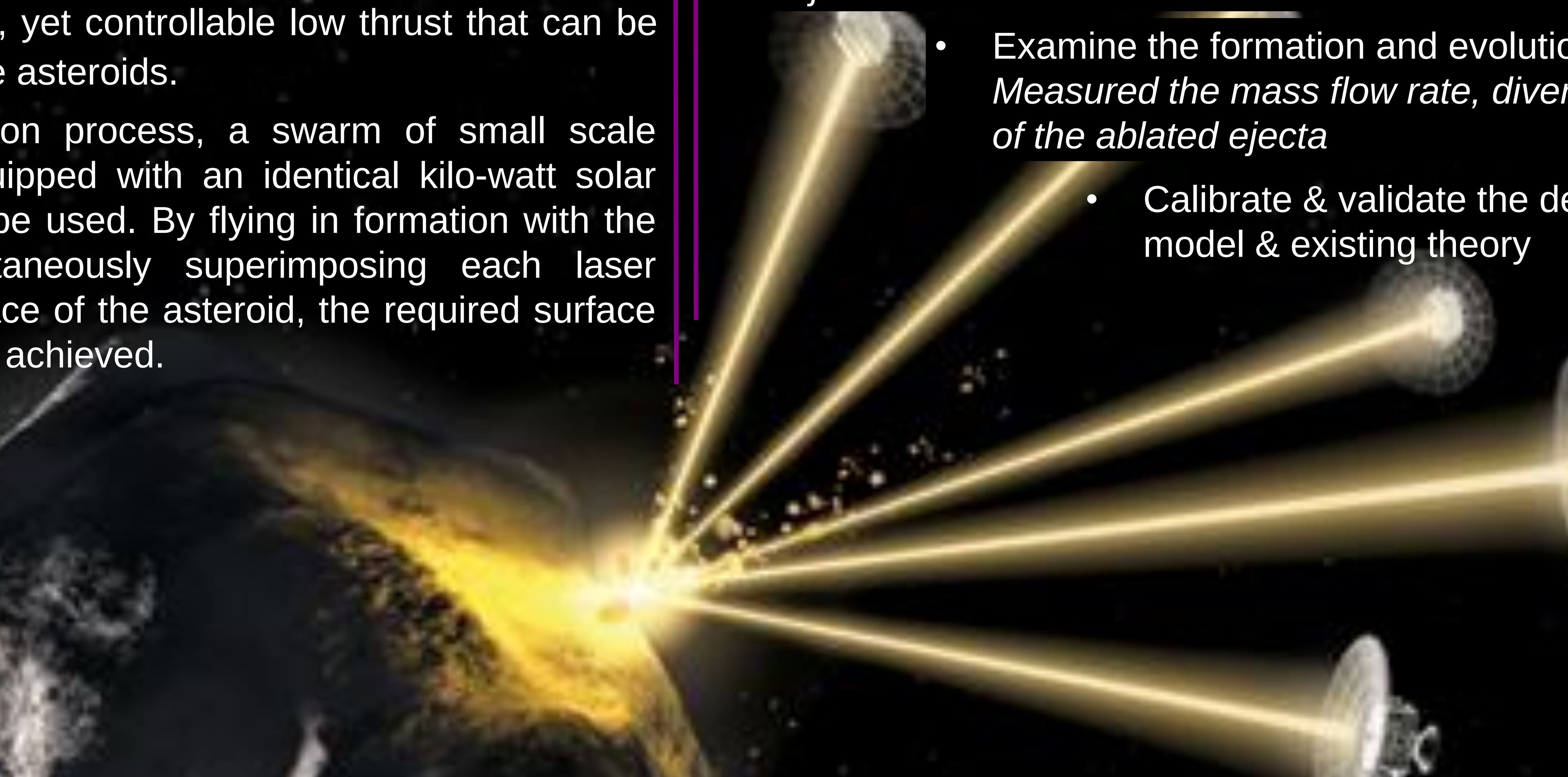
ASTEROIDS, THE RISK

Any asteroid-to-Earth impacting event could result in the wide spread, or mass extinction of life. To address this risk, laser ablation is being investigated as a justifiable and achievable technique for the successful mitigation and deflection 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 plume of ejecta acts against the asteroid, providing a continuous, yet controllable low thrust that can be used to deviate small to medium size asteroids.

To initiate the ablation process, a swarm of small scale spacecraft, each equipped with an identical kilo-watt solar pumped laser could be used. By flying in formation with the asteroid and simultaneously superimposing each laser beams onto the surface of the asteroid, the required surface power density can be achieved.

This results in the ablation of a small portion of the asteroid's surface. However each spacecraft becomes susceptible to the degrading affects of the condensed ejecta, expelled from the ablation spot. Further experimental work is required to fully verify the ablation process

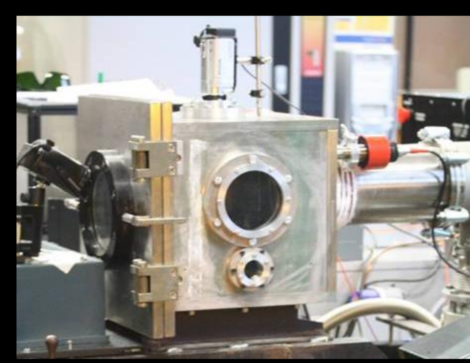


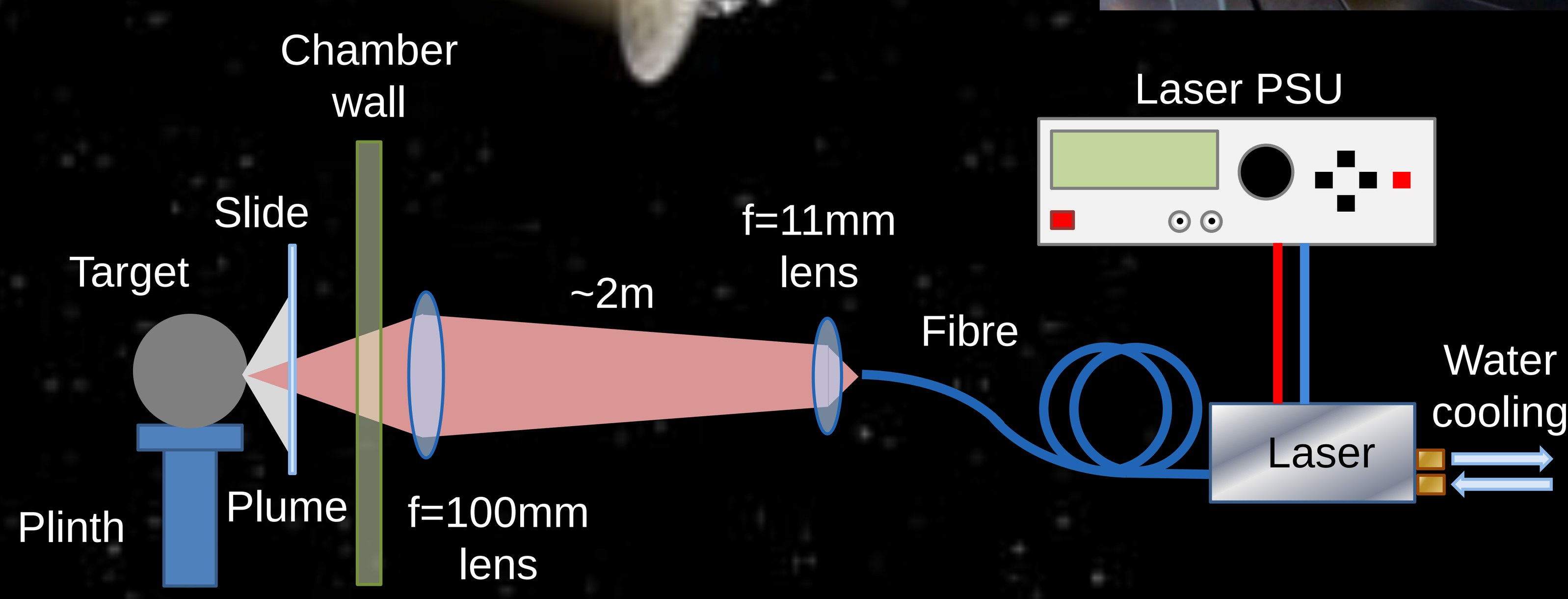
THE EXPERIMENT

To examine the laser ablation process a series of experiments using a 90 W continuous wave laser has, and is currently being performed. The ablated samples include sandstone, olivine and a highly porous composite mixture.

The experiment aimed to:

- Assess the potential for the ejecta to contaminate any exposed surface *Within the ablation volume the deposited ejecta was collected. This occurred at known distances from the spot location, on a number of collection plates. The height and composition of the deposited ejecta was determined. The reduction of transmittance of the collection plates caused by the deposited ejecta was also assessed.*
- Examine the formation and evolution of the ejecta plume *Measured the mass flow rate, divergence geometry and velocity of the ablated ejecta*
- Calibrate & validate the development of the numerical model & existing theory





ABLATION MODEL

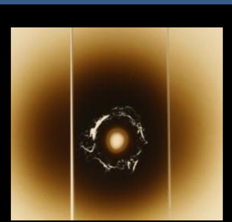
The laser ablation process is governed by three fundamental assumptions. This defines the nature and composition of the ejecta plume. Ejecta depends on the available energy & efficiency of the ablation process. These assumptions need to be experimentally validated, updated and/or eliminated.

Plume profile is similar to the rocket exhaust

The expansion of the gaseous ejecta is assumed to be comparable to standard methods of rocket propulsion. This assumes gas-only particles that expands uniformly, without any ionisation of the gas.

Asteroid is a spherical, dense, homogenous body

Forsterite (Mg_2SiO_4) is often used. This is considered to be a infinite heat sink with a constant internal temperature during ablation. However, asteroids exist over an extended range of compositions & surface features. The model must therefore be advanced to represent the diversity within the asteroid population. This includes loose rubble piles, monolithic and porous asteroids.



$$\tau = e^{-2\eta h}$$

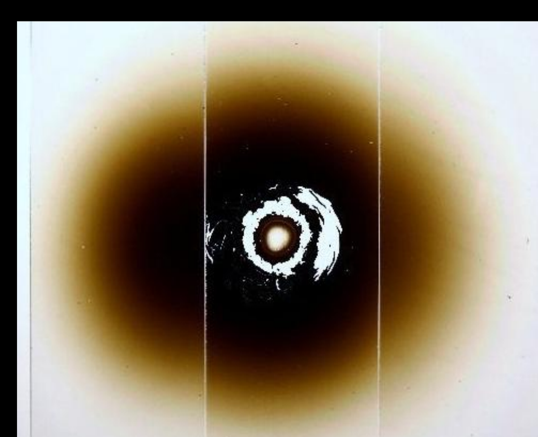
Ejected particles will immediately re-condense & stick

Within the vicinity of the ejecta plume any exposed surfaces – radiators, solar cells, multi-layering insulation, mirrors – will be subjected to the degrading affects of the deposited ejecta. This is assumed to follow the Beer-Lambert-Bouguer law. Ejecta will also attenuate the laser beam. Significant degradation will affect the intensity of the laser, its operational lifetime and the overall efficiency of the ablation technique.

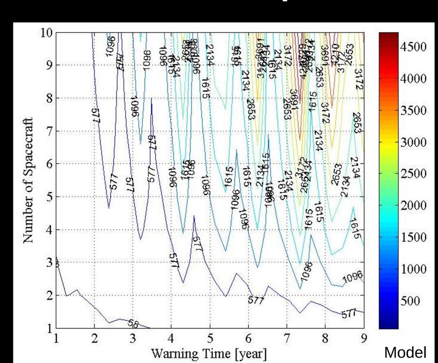
If proven successful laser ablation could also be used for the extraction of deep and previously inaccessible material. This could be used for remote sensing, in-situ and/or sample return missions. This would permit scientists to explore the composition & evolution of asteroids, and other rocky bodies.

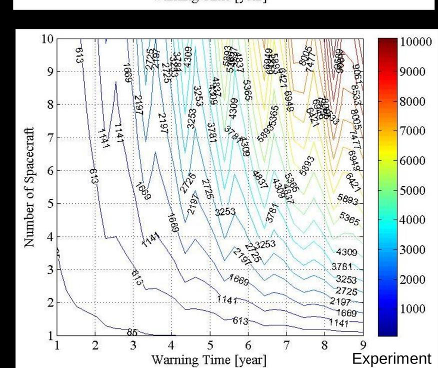
ANALYSIS

Laser ablation resulted in the formation of a gaseous plume of ejecta; similar to the development of a rocket exhaust. A comparable ablated mass flow rate between the experiment & the theoretical model was also observed. However, the ejecta did include some solid particles. This will enhance the transfer of momentum, and is not currently accounted for in the numerical model. The degrading affects of the deposited ejecta were also considerable different.



There was a significant reduction in the deposited ejecta density and absorptivity. No immediate saturation of the exposed surface occurred: not all of the ablated material stuck. The deposited ejecta can also be easily removed by applying a small vibration and/or an increase in surface temperature.





The experiment showed that the model was overly conservative.

Based on the assumed model parameters, over a 9 year period, with 10 spacecraft, a maximum deflection distance of 4500 km can be achieved. However, to represent a more realistic mission case the same scenario was re-computed based on the experimental results. This resulted with an 85 % increase in performance, with an maximum achievable deflection distance of 10000 km.

Laser Ablation Could Save The World!