ABSTRACT
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Title of Paper
Harvesting Near Earth Asteroid Resources Using Solar Sail Technology

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Abstract
Near Earth asteroids represent a wealth of material resources to support future space ventures [1]. These include water from C-type asteroids for crew logistic support, metals from M-type asteroids for in-situ manufacturing and liquid propellant, electrolytically cracked from water resources [2]. In this paper the role of solar sail technology will be investigated to support the future utilisation of near Earth asteroid resources including; surveying candidate asteroids through in-situ sensing, manoeuvring small near Earth asteroids, processing asteroid material resources and returning such resources to near-Earth space.

While solar sailing can be used directly as an efficient means of propulsion for transportation to and from near Earth asteroids, solar sail technology itself offers a number of dual-use applications. These include acting as a solar collector for large-scale power conversion. For example, at 1 astronomical unit, a 500m radius sail configured into a parabolic form [3] can in principle deliver of order 1 GW of thermal power. Such industrial-scale power is then available to efficiently process asteroid resources.

If an M-type asteroid is processed through thermal ablation using such a parabolic solar sail, then metal resources liberated are available to be manufactured into further reflectors, for example using additive layer manufacturing [4]. These new reflectors can then deliver additional thermal power. In principle, the resulting positive feedback process results in accelerated manufacturing, whereby an initial modest seed mass
delivered to Earth escape, in the form of a parabolic solar sail, can ultimately process most of an M-type asteroid into thin metallic film. For example, if the 500 m radius sail has an assembly loading of 10 gm\(^{-2}\) it represents an initial seed of mass of order 10 tonnes, although clearly additional infrastructure would be required for processing and thin film manufacture.

This accelerated manufacturing process will be modelled through a set of time-delay differential equations. It will be shown that due to the process delay \cite{5} in turning sublimated metal into thin metallic film the total reflector area, and hence total processed mass, increases as a polynomial rather than exponential function of time.

Once the processing of the M-type asteroid is complete, solar radiation pressure can then be used to transfer the reflectors to near-Earth space, either Earth orbit or an appropriate libration point. Here they can be re-processed into new structures or used directly, for example as collectors for space solar power in Earth orbit. While clearly speculative, the production and transport of bulk metals to Earth orbit could be achieved using a modest initial seed mass delivered to Earth escape. Solar sailing may well represent a key future technology for the harvesting of near Earth asteroid resources, using ambient sunlight both as heat for resource processing and radiation pressure for resource transportation.