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Space Resources, the Enabler of the Earth-Moon Econosphere (5)

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EXPANDING THE VIABILITY ENVELOPE AND DRIVING DOWN THE COSTS OF SPACE RESOURCE UTILIZATION BY IMPROVING TRANSPORTATION EFFICIENCY

Abstract

There is a good deal of uncertainty around the disposition, mining, and processing methods for resources on the Moon and asteroids. However, transportation factors are very well understood and very significant. A lunar polar water mine might burn 85% of the propellant it produces to deliver the remaining 15% to EML1. If we increase transportation efficiency, we reduce the requirements for ore grade, processing efficiency, and mining output. These reductions expand the viability envelope of a mining operation and reduce the investment required to satisfy a given demand.

Water as a feedstock for propellant production is the consensus first space resource. We model a range of likely propellant supply scenarios and tanker inert masses, iteratively using the rocket equation for the outbound and inbound leg while leaving propellant at a logistics hub. Assuming a constant departure mass, any inert mass reduction represents additional propellant that can be left at the logistics hub. A lighter tanker also needs less propellant for the return trip, and the excess can be left at the hub.

Our results show a range of mine output, and thus mine investment, reductions as a function of inert mass fraction and delta-v from the production site to the logistics hub. As an example, consider a lunar propellant mine that uses a single stage tanker to supply EML1. Changing the tanker inert mass fraction from 0.26 (as used in a recent NASA lunar ISRU study) to 0.1 (as in current Centaur upper stages) reduces the required propellant production by a factor of three.

We substantiate the possibility of significantly reducing inert mass by examining some drivers of mass that are present in Earth launched vehicles but absent in a lunar and asteroidal environment. These drivers include atmospheric thermal transfers, aerodynamic forces, the mitigation of aerodynamic forces through the use of cylindrical rather than spherical tanks, multi-gee axial and lateral forces with a multi-ton payload attached, and tanks that use pressure stabilization to support these loads.

Since the operating environment of a "space only" propellant tanker is in many ways more benign than that of an Earth launched vehicle, we should be able to make substantial reductions in inert mass relative to current upper stages. Aggressively pursuing the well understood and easily testable inert mass minimization of propellant tankers will expand the viability envelope and reduce the cost of resource utilization on the Moon and asteroids.